Metal Progress

NOVEMBER 1950

THIS ISSUE

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Flip the Flap→

As I was saying—

THIS MONTH I'll tell you about "Two Wonderful Guys". So here goes . . . .

I am one of those guys (not the guys I am writing about) who puts a mortgage on his farm so that he could have free enterprise and do just as Mrs. Bill wanted him to do and that was to purchase seats for "South Pacific". It would have been less expensive to have purchased tickets *to*, rather than *for*, the South Pacific! However, we felt fully repaid (although the mortgage isn't) and I enjoyed particularly seeing gorgeous Mary Martin "Wash That Man Right Out of Her Hair". But Mill kept remembering and humming Mary's other hit song, "I'm in Love with a Wonderful Guy"—and Mill meant Ezio Pinza (not me).

But I am one up on her because as I was saying, I know *two* wonderful guys. One of them comes by the title "Guy" naturally (it's his given name) and the other guy had to work hard and magnificently to acquire the title.

It's Guy Wainwright in the post position, president of Diamond Chain Co., Indianapolis, and it's Arthur Focke, his chief metallurgist, and the immediate past president of , who constitute the "great guy" twosome.

Art has given himself to the Society. He served four years on the Board of Trustees in preparation for the presidency and when his year came he entered into it with a vim and vigor that had the Secretary out of breath most of the time in his effort to keep up. Visiting 50 chapters in one year is a Herculean undertaking and all are happy that Art crossed the finish line with health unimpaired. Art left an imprint on every chapter before which he appeared. His counsel at the various local Executive Committee meetings sprang from his experiences as a chapter officer and a teacher and an educational director. He proved to thousands that he was a wonderful guy.

The other Guy fits right into the picture. He made it possible for Art to devote the tremendous amount of time to do a fine job. Guy has been an ASMember for over 30 years—joining soon after his return from metallurgical studies abroad. He is an example of a metallurgical engineer going to the top and a top executive who is glad to provide the time so that Art could serve the twenty thousand members of the .

So many thanks to both of you from all of the Society. Yes, indeed, a great pair and "Two Wonderful Guys"!

Cordially,

Bill

W. H. Eisenman, *Secretary*
American Society for Metals

IS *Heat Shock* WARPING YOUR FURNACE FIXTURES?

The extreme flexibility of these PSC jointed trays prevents self-destruction from warping and cracking. Most frequently used in roller or rail type brazing furnaces, these PSC units are recommended for use wherever higher-than-usual temperatures cause tray trouble. They are now standard with over a score of the largest automotive and metal-working firms.

PSC flexible trays are made in any length or width by assembling sheet alloy channels with tube spacers. In addition to flexibility, their light weight is another important source of operating savings. By eliminating many pounds of production-losing weight, PSC sheet alloy trays cut fuel costs and brazing cycles.

The unit pictured above, fabricated of Inconel, is 24 x 36 in., weighs about 50 lbs., and handles loads up to 80-90 lbs. However, we have made these trays in a dozen different sizes, and in as many different modifications of design to suit specific applications in brazing and other heat-treating operations.

As pioneer of light-weight sheet alloy heat-treating equipment, we offer you a wealth of experienced engineering assistance. The services of our technical staff are freely available.

Light-Weight **Heat-Treating Equipment for Every Purpose**

Carburizing and Annealing Boxes	Tumbling Barrels - Tanks
Baskets - Trays - Fixtures	Cyanide and Lead Pots
Muffles - Retorts - Racks	Thermocouple Protection Tubes
Annealing Covers and Tubes	Radiant Furnace Tubes and Parts
Pickling Equipment	Heat, Corrosion Resistant Tubing

PSC standard or special heat-treating equipment is furnished in any size or design. We fabricate the complete list of alloys, permitting you to choose the metal that is "alloy right" for your heat and corrosion requirements. Send blue prints or write as to your needs.

PSC EQUIPMENT IS "ALLOY RIGHT"

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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a full day's production . . . every day!

Mr. H. H. Manning, vice president of Champion DeArment says, "What we like about the Lindberg Induction Heating Unit is its accessability for inspection and preventative maintenance. It has been used 8 hours per day since its installation and we have had practically no interruption of production."

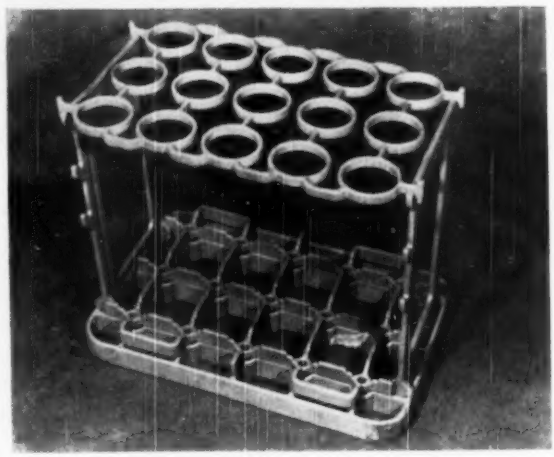
Champion DeArment Tool Company, Meadville, Pa., use the Lindberg 2-station Induction Heating Unit to harden their famous CHANNELLOCK pliers. Their unit, like all other Lindberg Induction Heating Units, is designed to give a full day's production every day . . . without costly, irritating breakdowns that skyrocket production costs ☆ ☆ **OVERSIZED COMPONENTS**—oversized components, built into every Lindberg Unit, insures uninterrupted production and hundreds of "bonus hours" of service life ☆ ☆ **SAFETY OVERLOADS**—safety overloads, designed for *any eventuality* protect valuable equipment, reduce rejects and guard against human error ☆ ☆ **"CHECKLITE" TROUBLE SHOOTING**—a built-in "CHECKLITE" system maintains a constant vigil, and when safety overloads operate a signal light indicates the location of the overloads for immediate correction ☆ ☆ For full details on 5, 10, or 25KW Units, write for Bulletin 1449. Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

LINDBERG

HIGH FREQUENCY DIVISION

GAS CARBURIZING TRAYS

Job-proven in Industry!



The design of gas carburizing trays and fixtures to obtain maximum service life requires a thorough knowledge and understanding of

- the effect of temperature differentials of each application.
- effect of black body conditions of each specific loading.
- effect of square corners and small radii.
- effect of unequal sections.
- effect of cooling rates in the mold, the furnace, and the quench tank.
- plus a complete knowledge of foundry techniques to obtain the highest quality castings.

Hundreds of trays are being used by industries with unnecessary designed-in self-fatiguing stresses which are costing the consumer thousands of dollars per year through decreased service life.

If you are interested in lower heat-hour costs, call an **ACCOLOY ENGINEER** for an honest analysis of your problem. There is no obligation on your part.

WE MAKE: MUFFLES · RETORTS · BELTS · CHAIN
ROLLER RAILS · CARBURIZING BOXES · SALT POTS

ALLOY *ENGINEERING* & CASTING COMPANY

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY CASTING CO. (DIVISION)
CHAMPAIGN, ILLINOIS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Now you can get...

BETTER FINISHES, BROADER USAGE

for **ZINC AND CADMIUM**

with

IRIDITE

for

CORROSION RESISTANCE, PAINT ADHERENCE, FINAL FINISH . . . BRIGHT, CHROME-LIKE OR COLORED

The only complete line of patented chromate-dip treatments to meet your particular finishing problem.

Iridite *quality* is *tops* in corrosion resistance and paint bond. Iridite finishes are *first* in wide selection of coatings:

BRIGHT: Chrome-like in appearance

BRONZE: Natural as bronze itself

OLIVE GREEN: A popular replica of Military Olive Drab.

HUE BRITE: Clear; eye-appealing iridescence

COLORS: Black, Red, Blue, Green

PROCESS METHOD: Simple dip chemical immersion for a matter of seconds

SURFACES: Zinc or cadmium: plated, die cast, galvanized or sheet

COST: The smaller fraction of a penny does a square foot of surface

FREE—Write for literature and samples, and for immediate action, send us a sample of the product you wish to process, along with the outline of your problem.

SPECIAL PROCESSES—*Research and new developments in general metal finishing are being carried forward as manufacturers present new finishing problems for us to work out.* ***Let us go to work on yours.***

IRIDITE LICKED THESE FINISHING PROBLEMS—Washing Machine Parts • Radio Equipment • Kitchen Utensils • Aircraft Parts • Lock Hardware • Office Machines • Window Frames • Vending Machines • Tools • Lamp Fixtures • Fuel Pumps • Carburetors • Auto Hardware • Zinc Coated Sheet • Hinges, Screws, Bolts • Camera Parts • Plumbing Fixtures • Wall Panels • Refrigerator Parts • Wire Products • Instrument Parts • Electrical Equipment • Armed Forces Materiel.

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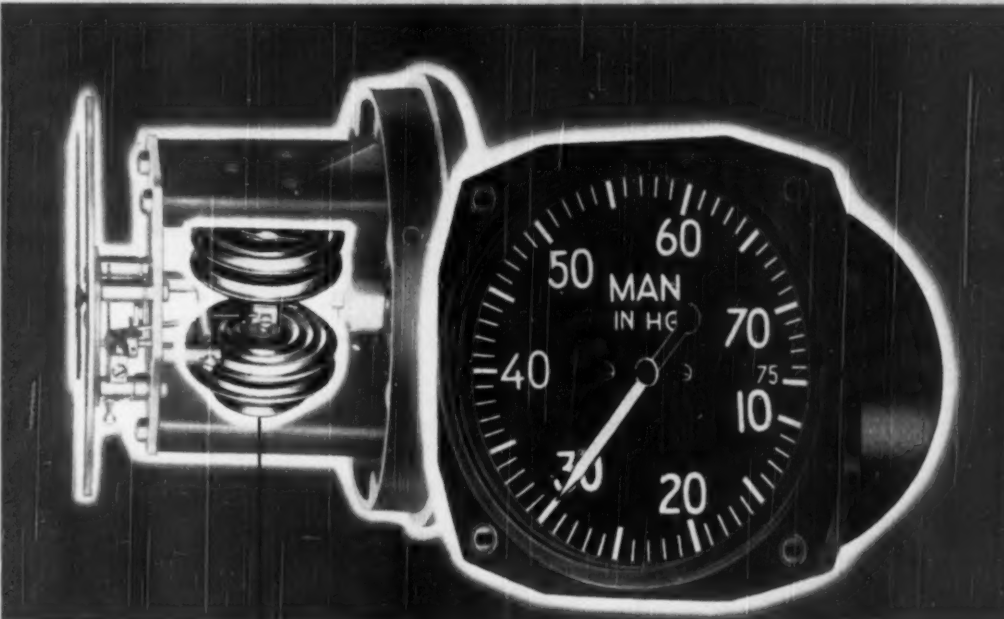
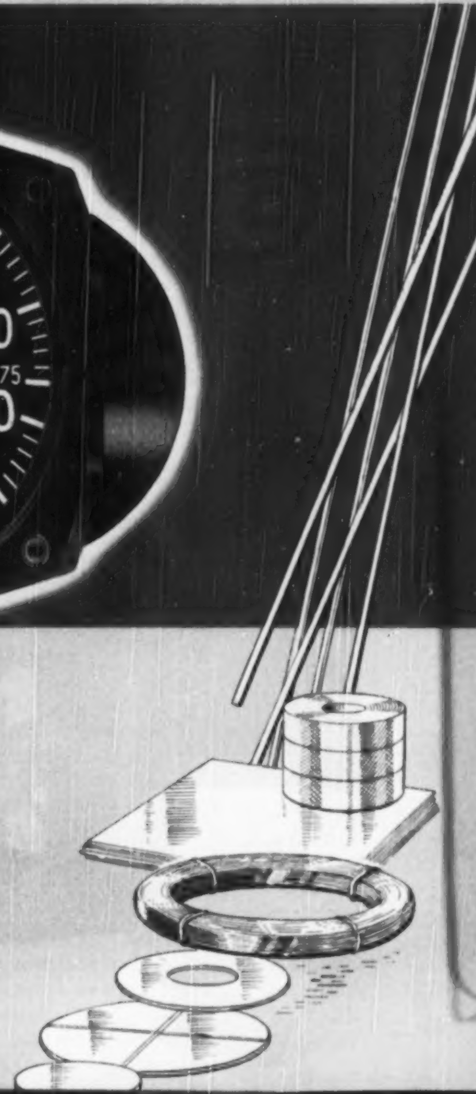
THIS TIRELESS METAL THAT KEEPS GAUGES HONEST MAY REVOLUTIONIZE YOUR PRODUCTS



United States Gauge, world's largest manufacturer of gauges, uses Riverside Beryllium Copper for both pressure and vacuum diaphragm capsules of its absolute pressure instruments.



There's no place for muscle-bound metals in the diaphragms of an absolute pressure gauge. Constantly *sensing and reporting* changes in manifold pressure of internal combustion engines, diaphragms must be super-sensitive yet rugged enough to withstand flexure.

Beryllium copper, one of the alloys made by Riverside, is the only metal possessing the necessary physical properties that will do the job economically. In this application beryllium copper is "cold worked" to a tensile of 80,000 pounds, and formed *while being heat treated* to a tensile of about 210,000 pounds. Beryllium copper diaphragms easily take the initial stresses caused by evacuating air and the ever changing stresses of flexure.

Because of these advantages—plus corrosion resistance, wear resistance, formability and superior electrical and thermal qualities—Riverside *Beryllium Copper* finds wide use in gauges, springs, thermostats, bearings, gears, valve sleeves and seats. This versatile alloy—or one of the other Riverside metals, *Phosphor Bronze, Nickel Silver* or *Cupro Nickel*—may be the specific answer to your alloy problem. We produce these alloys in standard or special grades to meet your requirements. And we'll be glad to work with your technicians in examining and solving your particular puzzle.

If alloys are giving you trouble—in processing or in service—send the case history to Riverside. Also, be sure to ask for our new pocket-size Alloy Handbook. It's invaluable as a handy reference and a guide to alloy specification—and it's yours without obligation.

RIVERSIDE
ALLOYS

phosphor bronze
•
nickel silver
•
cupro nickel
•
beryllium copper

Alloys developed by research, proved by use

THE RIVERSIDE METAL COMPANY
Riverside, New Jersey
Newark, N. J. • Cleveland, Ohio • Chicago, Ill.
Hartford, Conn. • Rochester, N.Y. • Detroit, Mich.

Export Agent: International Brass & Copper Co., Inc., 50 Broadway, New York City

Controlled QUENCHING PRESERVES THE *QUALITY!*

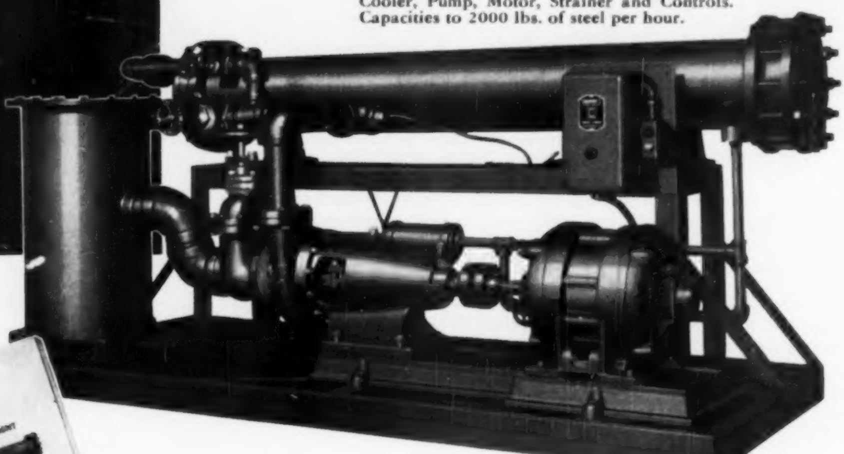
The degree of control exercised in quenching heat-treated metal determines the amount of time and materials wasted by sub-standard rejects . . . *and ultimate operating costs!*

You can be sure of better results if you rely on a B & G *Hydro-Flo* Oil Quencher. The temperature desired in the quench bath will be accurately maintained throughout the quench period. The oil will be strongly agitated to avoid formation of gas bubbles which cause irregular surface hardness. Your product will emerge *uniform in quality*—every time!

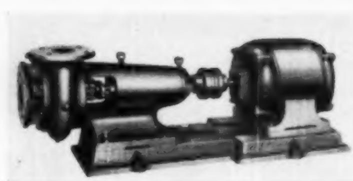
While B & G *Hydro-Flo* Oil Cooling equipment can be purchased in separate units for assembly on the job, many heat-treaters are buying B & G Self-Contained Coolers. The advantages are obvious—all parts are factory-assembled into one complete unit, ready for immediate installation.

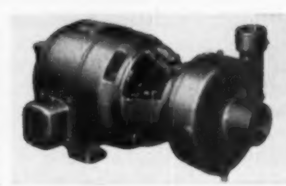
Bring your quenching problems to the B & G engineering department—there's no obligation in discussing them.

B & G Series "OC" *Hydro-Flo* Oil Cooler
Completely self-contained—equipped with Cooler, Pump, Motor, Strainer and Controls. Capacities to 2000 lbs. of steel per hour.



Send for this combined Catalog and Simplified Selection Manual.





A complete line of flexible and close-coupled centrifugal pumps. Send for engineering data.

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Hydro-Flo **OIL QUENCHING SYSTEMS**

*Reg. U. S. Pat. Off.

BELL & GOSSETT COMPANY
Dept. BU-16, Morton Grove, Illinois

Heat-treating equipment since 1916

Two type HD 2436 Hevi Duty Vertical Retort Furnaces in use at The Chain Belt Co., Milwaukee, Wis.

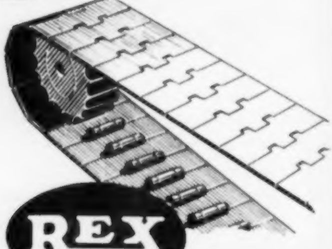


TABLE TOP CHAIN

is heat-treated in modern
HEVI DUTY FURNACES

For dependable results that add extra quality to Rex Table Top Chain, each section is case hardened in a Hevi Duty Furnace.

It's the *Reliability* of HEVI DUTY FURNACES

that enables you to CUT the COSTS of case hardening parts for your product

These versatile Hevi Duty Electric Furnaces at the Chain Belt Co., of Milwaukee are in daily use carburizing, hardening, and annealing the many diversified parts used in REX Chains.

Typical of the many heat treated parts are the sections of the popular REX TABLE TOP conveyor chain. Where minimum distortion during heat treatment is a necessity and accurate case depths must be maintained, Hevi Duty Furnaces are first choice.

Send for Bulletin HD 646

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES HEVI-DUTY ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS
MILWAUKEE 1, WISCONSIN

Bulletin on SUPER REFRACTORIES by CARBORUNDUM

TRADE MARK

NO. 12 NOVEMBER, 1950

How Can You be Sure of Proper Selection of Super Refractories?

The table below shows that the line of super refractories offered by The Carborundum Company includes several distinct product groups. Each has specialized characteristics — equally important in both high- and low-temperature applications. Beyond these basic groups, however, are many modified varieties, each developed to better withstand a particular combination of conditions. Consequently, the selection of the best possible material for a given installation becomes involved.

It is for this reason that you should have no hesitation in asking for the assistance of CARBORUNDUM field engineers. These men have had wide experience with super refractories and their application to many different types of furnaces and kilns.

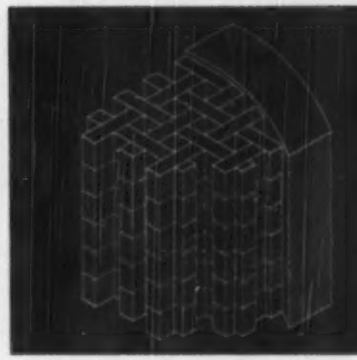
Supporting the work of these field engineers is CARBORUNDUM's technical group. Not only is this group close to both manufacturing operations and research programs — they are also in touch with developments throughout the world involving new processes using super refractories. These men have the broad product and application knowledge that is most helpful in considering unusual new installations.

You can be sure of getting the right super refractory for your job when you bring your problem to CARBORUNDUM.

Physical Properties of Super Refractories by CARBORUNDUM

Trade Mark

	CARBOFRAX Silicon Carbide	MULLFRAX Electric Furnace Mullite	MULLFRAX S Converted Kyanite	ALFRAX K Electrically Fused Alumina	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200° F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25° — 1400° C.)	.0000044	.0000059	.0000069	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2460° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.



Proper Use of CARBOFRAX Checkers Can Increase Gas-Make

With CARBOFRAX silicon carbide checker brick properly applied in carburetors, superheaters, and oil-gas generators by CARBORUNDUM field engineers, operators can increase their gas-make and lower their operating costs. CARBOFRAX checkers, because of their high thermal conductivity and high emissivity, absorb more heat in less time. For the same reasons the heat is released to the gas stream more rapidly during regeneration.

With their unusual refractoriness, great density and low iron content, CARBOFRAX brick last longer and provide cleaner checker settings. In other words — with CARBOFRAX brick you get better oil efficiency, increased cracking capacity, lower checker maintenance, and savings in the solid fuel.

Jig-saw — of CARBOFRAX Shapes!

These are some of the pieces that made up a refractory lining designed by CARBORUNDUM engineers for a metallurgical process. In all, there were several thousand pieces — and about 1000 of them were of different keyed, fitted shapes.

The problem was to furnish a lining that molten metal would not penetrate, that could withstand rapidly fluctuating

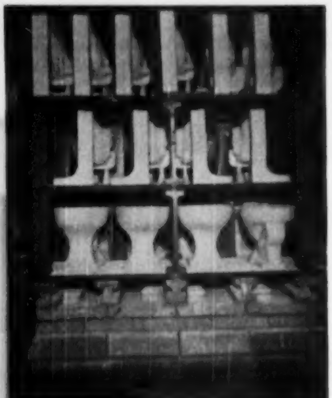
Address all correspondence to: Dept. C-110, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

Continued on other side →

← *Continued from other side*

pressures, and that would perform under unusually high temperatures. CARBOFRAX silicon carbide tile was the answer — in special and intricate shapes which would fit the complicated shell. With elbows and bends, every piece had to be keyed to fit, with accurate tight joints — and the completed lining mechanically stable.

The result? An amazing performance record, far surpassing any previous lining — more proof of what the correct grade of CARBOFRAX materials will do when engineered to the job.



Kiln Furniture Designed by CARBORUNDUM Engineers Improves Performance

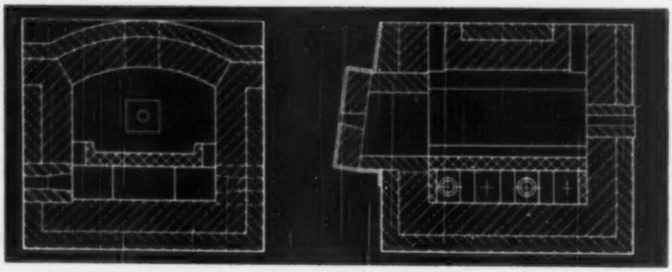
These are the advantages a sanitary-ware producer reports from using CARBOFRAX silicon carbide tile and CARBOFRAX streamlined posts in this car structure laid out by CARBORUNDUM engineers:

Greater loading capacity — With thin CARBOFRAX slabs and streamlined posts, there is more space for setting ware. Placing, too, is easier.

Fewer rejects — The clean CARBOFRAX kiln furniture prevents ware marking. Even after long service, there is no dripping and blistering.

Less frequent rebuilds — With CARBOFRAX furniture, cracking and warping are practically eliminated. Post deformation is no problem. Replacement and maintenance expenses are reduced to a minimum.

The properties of CARBOFRAX tile and posts make them unique for such applications. With their high hot strength, they can support heavy loads without sagging. With their exceptional resistance to heat shock, they will not crack prematurely. Their high thermal conductivity means quick, uniform heat transfer. All in all, they will increase production and lower costs.



Small Oven Furnaces — Perform Better When Super Refractories Are Properly Used

Increased production and operating economies almost always follow the installation of a CARBOFRAX hearth in a small oven furnace. The high thermal conductivity of this super refractory means rapid heat transfer, with quicker temperature come-back after charging, and more uniform heat distribution throughout the chamber. With cold spots eliminated, there are fewer rejects. Maintenance expense, too, is cut — with its high resistance to mechanical abrasion, and to cracking, a CARBOFRAX hearth lasts longer.

However, super refractories have even more possibilities in such furnaces. CARBOFRAX silicon carbide or MULLFRAX electric-furnace mullite supports last longer and improve quality of work by keeping the floor flat and level. Burner ports and door blocks of MULLFRAX S converted kyanite blocks promote more continuous operation, reduce maintenance. Even main linings will last longer — and improve furnace efficiency — when partially or entirely constructed of ALFRAX BI aluminum oxide brick or shapes.

For Melting Furnaces, Too Let CARBORUNDUM Engineers Select Your Lining ▶

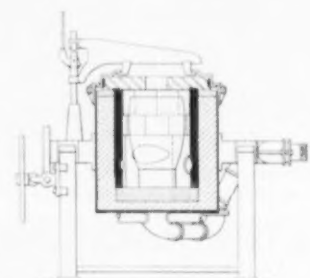
Non-ferrous metal melting furnaces, such as shown in the drawing at right, almost invariably give better results when properly lined with CARBOFRAX silicon carbide shapes:

Lining costs come down — With their high resistance to spalling, cracking and flame erosion, CARBOFRAX linings last longer. Lining costs are lower per pound of metal melted.

Production goes up — CARBOFRAX linings need be only 1¾-inches thick. Consequently heavier insulation can be used — and the heat capacity of the furnace structure will be lower. Melting rates are faster; you can get more heats per shift.

Maintenance costs are reduced — Not only do CARBOFRAX linings last longer, but when replacement is finally necessary, it can be made easily and quickly. The individual CARBOFRAX tile are accurate in size, and have rugged interlocking joints. Frequent patching can be avoided, too — saving further on labor costs.

CARBOFRAX linings are stocked in a wide variety of sizes. Special sizes can be produced quickly to order.



To obtain facts and figures on installations in specific fields merely select from this list of bulletins. Copies will be sent you at once. No obligation, of course.

- Super Refractories by CARBORUNDUM (general catalog)
- Super Refractories for the Ceramic Industry
- Super Refractories for the Process Industry
- Super Refractories for Boiler Furnaces
- Super Refractories for Heat Treatment Furnaces
- Super Refractories for Gas Generators
- The Frax Line of Cements
- CARBOFRAX Refractory Skid Rails
- Porous Media for Filtration & Diffusion

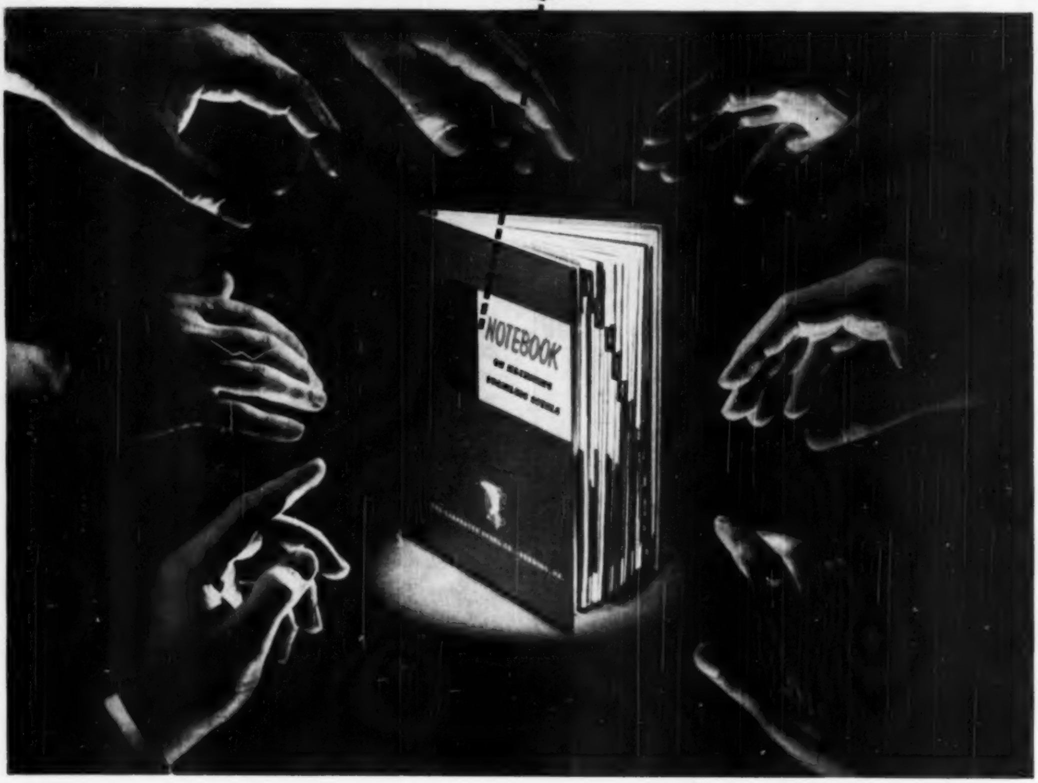
Dept. No. C-110

THE CARBORUNDUM COMPANY

Refractories Division

PERTH AMBOY, NEW JERSEY

X MARKS THE SPOT



...Where *Carpenter* Customers Find New Ways to Get Stainless Jobs Done Faster

It's easy to see how *less tool grinding* means less machine down time. And it saves because you make fewer tools. *Reducing the number of rejects* on Stainless jobs—getting the best possible finishes—can make a big difference in your unit production rate, too.

Many a customer of ours has found this a good formula for easier machining of Stainless. First use the Stainless that is *uniform* every time you get it—*Carpenter* Free-Machining Stainless. Then take advantage of the shop help Carpenter can give you.

For example, the men who work out of your nearby Carpenter Mill-Branch Warehouse will be glad to help out on any problems that come up. Or, we can give you a personal copy of the Carpenter "NOTEBOOK on Machining Stainless Steels". It's packed full of useful shop hints on turning, drilling, threading, milling, lubrication, etc. If you would like a copy, just write us a note on your company letterhead, indicating your title.

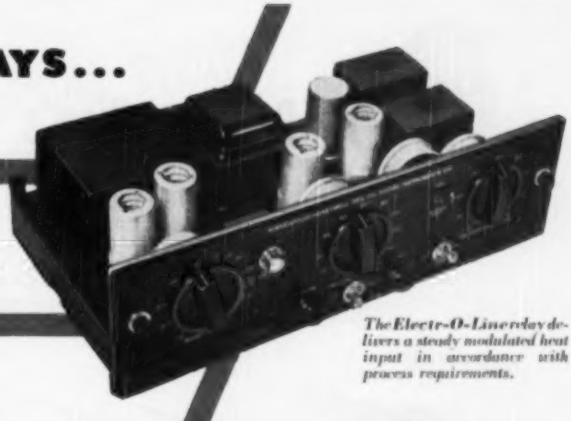
The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Department: Woolworth Bldg., New York 7, N.Y.—"CARSTEELCO"

Carpenter
STAINLESS STEEL
takes the problems out of production

For Easy-to-Use Stainless Call Carpenter. Warehouses in principal cities throughout the country.

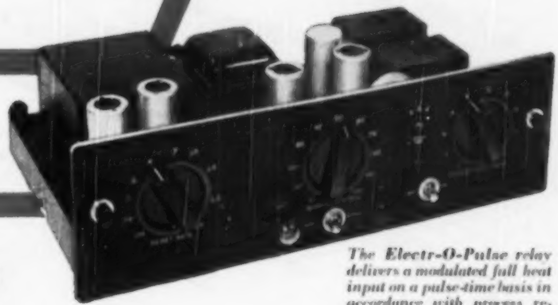
NEW CONTROL RELAYS...

Electr-O-Line



The Electr-O-Line relay delivers a steady modulated heat input in accordance with process requirements.

Electr-O-Pulse



The Electr-O-Pulse relay delivers a modulated full heat input on a pulse-time basis in accordance with process requirements.

FOR YOUR FURNACE
FOR YOUR PRODUCT

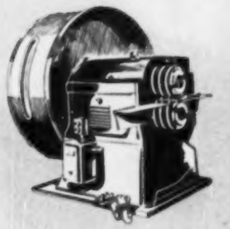
For Exacting Control of Industrial Furnaces, Brown offers two new relays: the *Electr-O-Line* for position proportioning control and the *Electr-O-Pulse* for time proportioning control. Completely electronic and both providing automatic reset, these units are designed as an integral part of Brown Proportional Controllers or as separate models for modernizing existing installations. Outstanding features include:

- *Control adjustments are completely independent making "tuning in" process very simple.*
- *Manual control of the process may be accomplished from the relay.*
- *Plug-in type chassis simplifies servicing and wiring.*
- *Both the **Electr-O-Line** and **Electr-O-Pulse** relays are physically interchangeable with the Brown Manual Reset relay when used with Brown **ElectroniK** Proportional Controllers.*
- *Designs are electronic and have no motor driven resistors.*

Brown Instruments, the most *complete* modern line of controllers, include the *right* control for your furnace . . . for your product. There need be no compromise on a control job . . . no need to "stretch" the application to fit the instrument. Your local Honeywell engineer can impartially advise you on the *correct type of instrument* for your requirements. Call him today . . . he is as near as your phone!

Minneapolis-Honeywell Regulator Co., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS



Reducerolling's really rolling along...

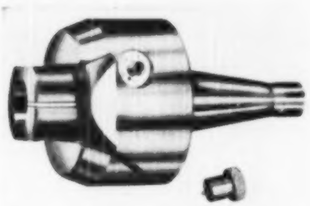
Typical REDUCEROLLED blanks shown on these pages indicate the extent to which this simple forging technique has been accepted by forgemen.

In a new approach to forge-shop cost-reduction, the rugged, versatile REDUCEROLL pre-forms blanks *quickly* for finish-forging on the same heat!


PREPARING FORGING BLANKS!
As important as buying the "best" machine is the engineering assistance and on-the-job service which the machine's builder provides.
NATIONAL engineers and service experts continue to be available—on a cost-free basis, for the entire life of your NATIONAL equipment—to assist you with any forging problem.
Whatever you need—die design, production procedures, maintenance, new development—NATIONAL'S long experience is "on call," yours for the asking!
Let us help you investigate the application of REDUCEROLLING to your work. Send us a print or sample of your forging—or, better yet, pay us a visit. No obligation, of course.
No. 4 REDUCEROLL
NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO.
DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES—MAXIPRESSES—COLD HEADERS—AND BOLT, NUT, RIVET, AND WIRE NAIL MACHINERY
Hartford
Detroit
Chicago

Engineering Digest of New Products

INTERMEDIATE SIZE BORING HEAD: An intermediate size offset boring head is now being marketed to supplement the other sizes of boring heads now manufactured by Everede Tool Co.



The new size No. 3-50 boring head is 3½ in. in diameter and has a maximum boring capacity of 4½ in. When equipped with an extension attachment it is possible to increase this capacity 100%. Containing the versatile features of both the smaller and larger models, the No. 3-50 boring head has been developed for use in popular size vertical mills, jig boring machines, and turret lathes.
For further information circle No. 1021 on literature request card on p. 672B

GEAR HARDENING MACHINE: New radio-frequency gear hardening machine, for high-production heat treating of gears, is available from Westinghouse Electric Corporation. This machine — the Inductall — is used with a vacuum-tube radio-frequency generator, a 10,000-cycle motor-generator set, and other associated equipment, to harden spur gears, cluster gears, integral spindle gears, and also shafts. The machine carries each gear through an automatic cycle for either through- or contour-hardening. Uniformity of hardening results from the mechanical gear handling system and precise electrical timing of the pre-heat, heat-treat, and quench operations. The Inductall system meets increased production requirements. It is simple to operate and maintain, and does not require skilled labor for operation.
For further information circle No. 1022 on literature request card on p. 672B

POWDER METAL PRESS: New S-5 40-ton powder metal press is a cam-operated unit for the production of electric motor, radio, and television parts, machine parts, cemented carbides, porous bearings and other powder metal pieces. New design, offered by F. J. Stokes Machine Co., largely eliminates the necessity for changing cam inserts and changes in set-up are accomplished in a fraction of the time formerly required. A single hand wheel adjustment sets the machine for the proper compression level of the lower punch, automatically taking care of the ejection level by this single setting.

The press may be used for sizing or coining as well as for forming through the use of a special attachment. When used as a sizing press, the parts may be fed either by hand or automatically at full speed.
For further information circle No. 1023 on literature request card on p. 672B

COPPER CLEANING SHOT: New copper cleaning shot, specially designed for the nonferrous trade has just been announced by the Harrison Abrasive Division of Metals Disintegrating Co., Inc.

The manufacturer claims that this new product solves the cleaning problem of those who cast and finish in brass and bronze. L/D Copper Cleaning Shot, as the new shot is called, cleans the casting by the force of its impact, yet does not imbed itself. Thus, it becomes possible to obtain the fine finish which results from "working" the surface of the casting without cutting it. It can be used either in an air or wheel-type machine and for all types of nonferrous castings and pieces. In addition to its use with brass and bronze, it is also very effective when used for blasting aluminum pieces in order to obtain a uniform finish. While designed specifically for the nonferrous casting trade, it is also applicable to all types of cleaning and finishing where a light finish is desired.
For further information circle No. 1024 on literature request card on p. 672B

NEW ELECTRIC CONTROL: New control system just announced by Leeds & Northrup Company — P. A. T. '50 — introduces rate action into an electrically-actuated control. The significance of rate action is that it responds according to the speed with which the controlled variable changes — and thus improves process output by reducing the length of time that an upset can force the controlled process off its set point.

If furnace temperature, for example, begins to fall, rate action immediately opens the fuel valve. The faster the drop in temperature, the wider the valve is opened. And as the rate of temperature departure decreases, rate action's effect also decreases — "putting on the brakes" to bring temperature smoothly back in line.

Like the previous L&N model, P.A.T. '50 also has proportional and reset control actions, and is applicable to the regulation of temperature, pH, chemical concentration and gas analysis.
For further information circle No. 1025 on literature request card on p. 672B

CENTRIFUGAL CASTINGS: New equipment to produce larger sizes has been added to the centrifugal casting department at American Non-Gran Bronze Co. The company now offers centrifugally-cast liners,

sleeves, rolls, rings, bushings, etc., in bronze alloys — rough or machined — up to 12 in. O.D. and 13 in. in length.
For further information circle No. 1026 on literature request card on p. 672B

Engineering Digest of New Products

METALLOGRAPH: A radically new and improved metallograph is announced by American Optical Company, Instrument Division. Designed as a routine control instrument, it offers superior optical performance together with convenience and simplicity of operation.

This new instrument represents a progressive step in the field of metallography. All controls and adjustments are within easy reach. Directly in front of the operator are the 5 x 7-in. camera, the monocular or binocular microscope eyepieces, and the ball-bearing mechanical stage. Within easy reach is the electrical control panel for the arc and visual lamps. The four objectives on rotating turret, the photographic eyepieces mounted on a quick-change slide, the camera shutter and the color filters . . . all are operable from a sitting position.

The optical systems for photography and visual observations are coupled to permit all focusing to be done through the visual system, eliminating the necessity for ground glass focusing.

Grain size measurements, ferrous or nonferrous, are compared directly on the ground glass with standard grain size charts. Case depth and linear measurements are easily and accurately made with an accessory micrometer rule. Selection of magnification is a very rapid procedure. No

tables or charts are required. The objective, eyepiece and camera bellows setting are all identified by the standard A.S.T.M. magnifications. These range from 50 to 1500 × with 2000 × available on special request. Monocular or binocular bodies are available. A built-in visual lamp reduces the use of the arc lamp to photography only. Either a ribbon filament tungsten lamp or fully automatic motor-driven arc lamp may be selected to suit individual needs. The metallograph is equipped with a standard Graflex camera back using inexpensive double plate holders. The photographic eyepieces, on a quick-change slide, are especially designed for optimum photographic results.

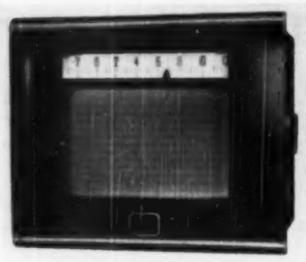
For further information circle No. 1027 on literature request card on p. 672B

SAND WASHER: The recommendations of the Committee on Foundry Sand Research of the American Foundrymen's Society for the determination of the clay content of foundry sands call for the agitation of the sand in water and the removal of the clay which remains suspended in the water. All the various steps required in the method are easily taken care of by the new sand washer brought out by the Claud S. Gordon Company. This washer employs a centrifugal unit to remove the clay from the sand grains. A single-blade impeller driven at high speed by an electric motor throws the sand grains against baffles suspended in the beaker containing the sand and water. A syphon with the inlet exactly 1 in. from the bottom of the beaker is used to remove the wash water from the beaker. The syphon action is started by first compressing the rubber bulb and then closing the outlet end of the tube with one finger and releasing the bulb. The washer is available in two models — a single-unit washer with one graduated Pyrex beaker; and a six-unit washer with six beakers.

For further information circle No. 1028 on literature request card on p. 672B

Engineering Digest of New Products

STRIP-CHART ELECTRONIC INSTRUMENTS: The Bristol Company announces the development of a new



line of strip-chart electronic instruments, described as the Series 500 Strip-Chart Dynamaster Electronic Instruments. The Strip-Chart Dynamaster is a high-speed, self-balancing a-c bridge designed for measurement of temperature, resistance, conductivity, strain, position, inductance, pressure, force, or any other variable which can be measured in terms of impedance. In addition, the instrument can be used for electric power totalization and as the receiver for Bristol's Metameter System of Telemetering.

The measured variable is recorded on a chart 11¼ in. wide and indicated on a large scale which is legible at a distance. In addition to the single-record model, instruments are available for as many as 16 different records on the same chart.

For further information circle No. 1029 on literature request card on p. 672B

METALLOGRAPH: Bausch & Lomb Optical Company announces a new metallograph. This new Balphot Metallograph provides equipment that combines the economy of more limited capacity instruments with many of the performance advantages of the most advanced metallographs.

These are some of its outstanding features: *straight-line observation* — the Magna-Viewer screen, stage, microscope and eyepiece are all in one line, for easy direct observation. *Centralized controls* — All controls are within easy sight and reach of seated operator. *New fine adjustment mechanism* — Raises and lowers stage 0.1 mm per revolution of fine adjustment knob; knob is graduated to measure travel; ball bearings provide smooth, backlash-free motion.

Another new feature is the Magna-Viewer, which provides screen images with good contrast and uniform brightness. Use of the screen eliminates the fatigue of prolonged eyepiece observation, resulting in better, faster work in such operations as grain size determination and dirt counts.

For further information circle No. 1030 on literature request card on p. 672B

DETERMINATION OF CARBON-BY-COMBUSTION: Announcement has been made of the availability of the Combustron, new electronic instrument for rapid and accurate determination of carbon-by-combustion. Offered by Burrell Corporation, the Combustron is a compact, bench-mounted, self-contained instrument; it comes fully equipped, ready to plug into the power supply. It employs induction heating and has exclusive features which have been incorporated after extensive research in both the laboratory and the field. Some of

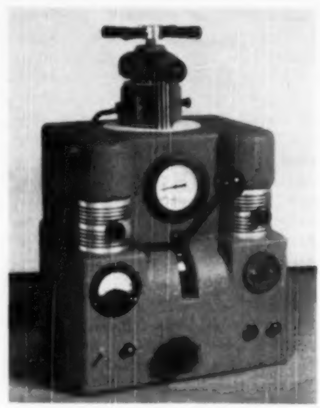
these features are: instant heating, rapid analysis, visible combustion, a sturdy Vycor reaction tube, and availability in one or two-tube models.

For further information circle No. 1031 on literature request card on p. 672B

New Products

SPEED PRESS: New No. 1330 AB speed press announced by Buehler, Ltd., is the result of long and exacting experiments to provide the metallurgist with a new tool for the speedy and practical preparation of mounted specimens in either opaque Bakelite or the crystal clear plastic compounds.

Besides the streamlined modern design of this new AB press of 10,000-lb. capacity, the accessories such as molds, heating and cooling blocks are quickly interchangeable for the various size requirements. This new press is not restricted to opaque thermosetting Bakelite compounds; it is equally practical for the preparation of crystal clear thermoplastic AB Transoptic specimen mountings.



The AB speed press is arranged for interchangeable use of hardened stainless steel mold assemblies to produce 1, 1¼ and 1½-in. mountings. A model of higher capacity can be provided for larger requirements. This hinged press head is supplied with a semi-automatic lock and a hand wheel screw to lock the mold securely.

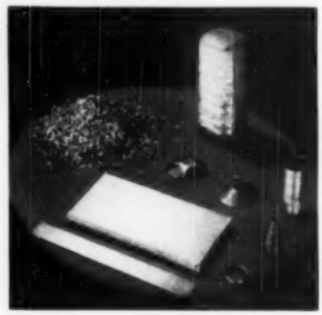
The heating blocks are arranged with a magnetic closure to snugly envelop the mold assembly. The interchange of thermostatically controlled heating units of 600-watt capacity for the various size molds is facilitated by convenient supports. The cooling blocks are located in a practical position in front of the AB speed press cabinet.

For further information circle No. 1032 on literature request card on p. 672B

New Products

NEW STRUCTURAL METAL: A high-purity, ductile vanadium metal is now available in limited quantities for fabrication and use by the metal industry, it has been announced by Electro Metallurgical Division of Union Carbide and Carbon Corporation. The metal averages above 99.8% vanadium and can be obtained in the form of ingots, bars, sheet, and foil. It is also available in the form of chips for remelting into ingots of special sizes and shapes.

Pure vanadium has good corrosion resistance, high tensile strength and excellent ductility. It is highly resistant to corrosion by salt spray, sea water and reducing acids in moderate concentrations, and tests to date indicate that it has good anti-fouling characteristics.



Vanadium ingots can be hot-rolled at temperatures between 1475 and 2100° F. Rolling practice, with respect to passes and reduction, follows that established for austenitic stainless steels. Sheet bar stock does not work-harden appreciably even during cold-working and may be rolled to a sheet having a thickness of 0.020 in. In fact, a reduction of 85% can be made without intermediate annealing.

The machinability of vanadium is about the same as that of cold-rolled steel. The metal is free-cutting and can be machined more readily than nickel, stainless steel, and titanium.

Vanadium metal has good workability and may be formed, bent, stamped, and pressed in the usual manner. For example, the Belleville-type springs shown were made in a simple lead-lined die. Vanadium may be welded by the Heliarc process using an argon atmosphere.

For further information circle No. 1033 on literature request card on p. 672B

1034. Abrasive, Cleaning

Bulletin 59 describes newly developed abrasive for blast cleaning. Tru-Steel Shot, a tough, hard, full heat treated abrasive that provides longer wear life and improved product finish. *American Wheelabrator Co.*

1035. Abrasive Wear

Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

1036. Alloy Casting Booklet

A new two-color 16-page booklet No. 112 describes the various heat-resistant, corrosion-resistant, and abrasion-resistant alloy castings, and includes descriptions of properties of many alloys available. Tables and charts show mechanical and physical characteristics in convenient form. *Michiana Products Corp.*

1037. Alloy Handbook

New pocket-size Alloy Handbook. It's a mine of nonferrous alloy information — and it's yours for the asking. *Riverside Metal Co.*

1038. Alloys

New catalog, "Electromet Ferro-Alloys and Metals", lists over 50 metals and alloys and describes unique technical service offered to the metal industries. *Electro Metallurgical Div.*

1039. Alloys, Fabricated

Catalog available showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

1040. Alloys, Hardfacing

New 20-page illustrated catalog gives detailed information on the complete Airco line of hardfacing alloys. Includes typical uses, mechanical properties and brief outline of recommended procedures. *Air Reduction Sales Co.*

1041. Aluminum

Copy of "Alcoa Aluminum Impact Extrusions" will be sent on request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

1042. Bearing Balls

New booklet, first of its kind, contains practical, authoritative information on use of bearing balls, burnishing materials and finishing barrels, in addition to catalog of products. *Abbott Ball Co.*

1043. Beryllium Copper

Helpful engineering information contained in new series of Beryllium copper technical bulletins. *Beryllium Corp.*

1044. Castings

Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

1045. Castings, Steel

New bulletin describes Pyrasteel, the chromium-nickel-silicon alloy with prime qualities for resisting oxidation and corrosion up to 2000°F and for withstanding most concentrated or dilute commercial acids and corrosive gases. *Chicago Steel Foundry Co.*

1046. Cast Irons

"Production of Nodular Cast Irons with Cerium" gives details of actual practice in adding cerium to the foundry melt as developed by the British Cast Iron Research Association. First release in America. *Cerium Metals Corp.*

1047. Combustion Chambers, Graphite

M-9602 describes the graphite combustion chambers and "Karbate" impervious graphite burner nozzles. Outlines operation of the complete system and points out the principal features, such as long life, absence of corrosion, minimum maintenance, ability to withstand thermal shock, simplicity and moderate installed first cost. *National Carbon Co.*

1048. Control Devices

New 64-page catalog 8303 illustrates over 100 different industrial control devices for temperature, flow, pressure, liquid level, and humidity. *Brown Instrument Div.*

1049. Copper Sheets

New 23-page booklet, the product of a ten-year program of design developments and tests combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc.*

1050. Corrosion

New catalog tells the complete story of industrial rust prevention. Includes three dozen different kinds of services and applications, with an important feature of seventy color chips, for easy identification. *Rust-Oleum Corp.*

1051. Cutting Oils

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

1052. Electrodes

New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low alloy, low hydrogen electrodes. It shows the importance and effectiveness of low hydrogen electrodes in welding low alloy, high tensile steels, mild steel under highly restrained conditions, and sulphur-bearing free machining steels. *Arcos Corp.*

1053. Finishes

Full information and samples on Iridite Al-Coat finishes for aluminum surfaces. *Allied Research Products.*

1054. Finishes

Bulletin 1400 tells how the new Hydro-Finish provides cleaner, smoother surfaces prior to coating processes; saves hours on the production line. *Pangborn Corp.*

1055. Finishing

80-page booklet, containing many charts and 68 large illustrations, covers Wear and Surface Finish in nine comprehensive chapters. *Gisholt Machine Co.*

1056. Finishing

New booklet, "Polishing Cloth and Abrasives", furnishes first-hand description and classification of some of the most used but least described accessories in modern sample preparation. *Buehler, Ltd.*

1057. Finishing

Alodine coating chemical protects aluminum and its alloys with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. *American Chemical Paint Co.*

1058. Forging

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co.*

1059. Forgings

New booklet, "The Improvement of Metals by Forging", gives full details on forgings with controlled directional properties for durability, economy, strengths and machinability. *Steel Improvement & Forge Co.*

1060. Free-Machining Bar Steel

Reprint of article entitled "La-Led, A New Free-Machining Bar Steel", by Glenn D. Bayer, metallurgist at LaSalle Steel, discusses the advantages and characteristics of the new steel. *LaSalle Steel Co.*

1061. Furnace, Atmos

The tangential firing principle a
controlled atmosphere system of t
furnace is described and illustrated i
F1. Included is discussion of con
phere requirements for tool and die
ware Tool Steel Corp.

1062. Furnace, Heat T

Radivection, a new development i
furnace design in temperature range
1750°F, is discussed in technical
Standard American Engineering Co.

1063. Furnaces

Bulletin 815-AB gives details for
duction economy with reciprocat
American Gas Furnace Co.

1064. Furnaces

New all-purpose furnace describ
HD-646 may be used for carburiz
dry cyaniding, bright annealing and
ing. *Hevi Duty Electric Co.*

1065. Furnaces

New bulletin on Malleable Ir
Furnaces contains photographic de
sectional drawings of this furna
describes the low-hydrogen gas
controlled-atmosphere malleable an
croft & Co.

1066. Furnaces

Complete "Buzzer" catalog availa
Buzzer high speed gas furnaces desi
for heat treating high carbon and a
also atmosphere pot hardening fur
cyanide and lead hardening. *Charles*

1067. Furnaces

New 32-page fully illustrated
Vapocarb-Hump furnaces. Descri
control method of regulating at
features improved control by use
assembly. *Leeds & Northrup Co.*

1068. Furnaces, Hard

Catalog A18 tells the story of th
ening Furnaces for versatile, ec
treating to save on hardening cost
tool production. *Sentry Co.*

1069. Gas Generator

Bulletin 1-11 describes how fu
generator Model 1 M1HE, rate
gives accurate proportioning and
analysis over full operating range.
adjusts for manufactured, natural, p
or refinery gases. *C. M. Kemp Mf*

1070. Gray Iron

Revised summary of Gray Iron
available in 4-page bulletin contai
of fourteen separate sets of gray iro
including a change in ASTM A-15
A-159-49T and the addition of two
tions covering automotive irons
Gray Iron Founders' Society.

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amount of postage stamps must be affixed for ret

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

1071. Heating Elements, Electric
Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

1072. Heat Treating
Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Send for literature. *Barrett Div., Allied Chemical & Dye Works.*

1073. Heat Treating
Bulletin SC146 outlines an improved process using a time-temperature program control for annealing steel forgings and other parts. Radiant tube-fired and direct-fired installations are fully described and illustrated. *Surface Combustion Corp.*

1074. Heavy-Duty Forgings
16-page booklet on "Heavy-Duty Forgings", profusely illustrated, shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co.*

1075. Heavy-Duty Oils
New 12-page illustrated booklet tells how Sunvis H.D. 700 oils keep machines clean, prevent rusting, do not foam, and provide longer service life in circulating and hydraulic systems, compressors, and gear boxes. *Sun Oil Co.*

1076. Induction Heating
More economical production made possible through redesign of heat treating methods. Full details on application to individual plants furnished in booklet, "A Tocco Plant Survey — Your Profit Possibility for 1950". *Ohio Crankshaft Co.*

1077. Induction Heating
Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

1078. Induction Heating
Send for bulletin 13-A containing countless new ideas to make tough forging specifications seem easy. *Ajax Electrothermic Corp.*

1079. Lubricants
Interesting facts on how shop operation can be more efficient and economical through the use of right lubricants described in "Metal Cutting Fluids". *Cities Service Oil Co.*

1080. Lubrication of Hot Metals
New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

1081. Machine Design
Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

1082. Metallograph
12-page catalog describes this completely new all-in-one desk-type unit for metallographic work. *American Optical Co.*

1083. Metal Spinning
New Spincraft data book — a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

1084. Microcastings
This 16-page booklet describes many applications for microcasting and also explains the process itself. *Microcast Div., Austenal Laboratories.*

1085. Microscopes
Catalog D-1010 illustrates and describes new E series microscopes for the most exacting research work. *Bausch & Lomb Optical Co.*

1086. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

1087. Oils, Cutting
For the right combination to suit your specific requirements, write for the booklet, "Cutting Fluids for Better Machining". *D. A. Stuart Oil Co.*

1088. Organic Solvents
64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use. Pocket size for easy reference. *The Solvents & Chemicals Group.*

1089. Plating Generators
For electroplating, anodizing, electrocleaning or electropolishing in either large-scale or small operations, there's a Columbia M-G set available for you. Catalog MP-700 sent free on request. *Columbia Electric Mfg. Co.*

1090. Polishing Machine
As a result of continued demand, the new 484 Duplex Polishing machine has been developed for quality finish on small cylindrical work. Equipped with two polishing heads, it employs the use of abrasive, felt, leather or fabric belts, depending on finish desired. *Production Machine Co.*

1091. Polishing, Metallographic
For preparation of fine metallographic specimens, a sturdy, smooth-operating table-model metallographic polisher is described in bulletin 90. *Eberbach & Son Co.*

1092. Pyrometer
Catalog No. 80 illustrates and describes the Pyro Optical Pyrometer for quick, accurate temperature readings on minute spots, fast-moving objects and small streams in a temperature range from 1400°F to 7500°F. *The Pyrometer Instrument Co.*

1093. Quenching Oil
New technical bulletin describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

1094. Refractories
Complete details on refractory cements for every nonferrous melting operation are available in catalog 863. *Norton Co.*

1095. Rolling Mill Machinery
New 30-page rolling mill machinery catalog covers machinery for blooming, slabbing and billet mills; merchant, bar and structural mills, rod mills, sheet and strip, plate mills, tube and pipe mills, rail mills and special custom-built equipment. In addition, it contains diagrammatic layouts showing the design and construction of complete mills. *Birdsboro Steel Foundry & Machine Co.*

1096. Rust Preventives
Two new transparent rust preventives, which replace heavy, opaque, gummy compounds formerly used for export shipment and the lacquer or varnish coatings, are discussed in new 4-page bulletin on Nox-Rust Clear Coat 626 and Clear Coat 607. *Nox-Rust Chemical Corp.*

1097. Salt Baths
32-page bulletin entitled "Houghton Liquid Salt Baths" discusses the advantages of this process for tempering, brazing, annealing, hardening, reheating, and carburizing. Also contains many pages of factual heat treating data. *E. F. Houghton & Co.*

1098. Steam Drop Hammers
Profusely-illustrated 24-page brochure describes construction of steam drop hammers. *Erie Foundry Co.*

1099. Steel, Cold Finished
16-page bulletin entitled "You Can Make Them Better with Cold Finished Jalcase" gives technical information, charts and graphs about Jalcase 10 and the other nine grades of Jalcase. *Jones & Laughlin Steel Corp.*

1100. Steel Selector
Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

1101. Steel, Stainless Machining
New "Notebook on Machining Stainless Steels" contains a wealth of useful shop hints on turning, drilling, threading, milling, lubrication, etc. *The Carpenter Steel Co.*

1102. Steels, Alloy
New book is now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy Data Book". *Wheelock, Lovejoy & Co.*

1103. Thermocouples
Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

1104. Thermocouples
New Catalog No. 5 contains full list of pyrometer supplies and buyers' guide showing how to get better control at lower costs by means of these new, easily assembled units for all makes of pyrometers. *Arklay S. Richards Co.*

1105. Tool Steels
To get the best results from your present equipment, send for the new 189-page Carpenter Tool and Die Steel Manual. *Carpenter Steel Co.*

1106. Tungsten and Molybdenum
New 24-page illustrated booklet on tungsten and molybdenum covers metallurgy, physical, mechanical and chemical properties, uses and applications, fabricating techniques and available forms. Of particular new interest are seamless molybdenum tubing and molybdenum parts with protective coatings for high temperature service in air. *Fansteel Metallurgical Corp.*

1107. Turbo-Compressors
Bulletins available as follows: Data book 107, Gas Boosters 109, Four-Bearing 110, Blast Gates 122, Foundry 112. Descriptive bulletin 127 and Technical bulletin 126. Send for each by number for particular application. *Spencer Turbine Co.*

1108. Valves, Safety
New series "LT" Lock-Tite safety valve making possible instantaneous gas shut-off under any or all unsafe conditions. Described in bulletin M-302. *Eclipse Fuel Engineering Co.*

1109. Welding
Information available on fast, clean process for welding sheet steel with the Heliarc torch. *Linde Air Products Co.*

1110. Zinc, Coatings
16-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. *St. Joseph Lead Co.*

[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

November, 1950

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The bundle of sticks

A wise old man called his quarrelsome sons about him. Taking up a bundle of sticks, he commanded each in turn to break the sticks. All tried, but in vain, and said it could not be done.

"And yet, my boys, nothing is easier to do," said the father, as he undid the bundle and broke the sticks, one by one. "By this example, you can see that united you will be more than a match for your enemies; but if you quarrel and separate, your weakness will put you at the mercy of those who attack you."

The useful truth of this fable is just as timely today as it was when the Greek ex-slave Aesop told it 2,500 years ago. You, a patriot, believing in individual liberty and freedom for all, see our American way of life threatened by the menace of communism abroad and jeopardized at home by complacence, negligence, confusion and incompetence.

As a business leader in your own community, you have a particular responsibility to help unify your fellow citizens and guide their thinking and action--for the strengthening and preservation of the ideals that built America, in fact, made America the envy and goal of the very individuals now seeking to destroy it. *In Union there is Strength.*

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General Offices--Youngstown 1, Ohio

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MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

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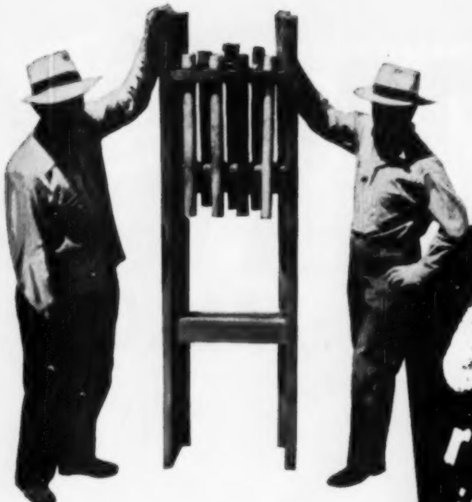
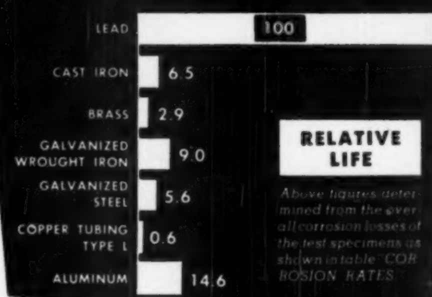


The wooden rack assembly supporting the seven pieces undergoing tests in the manhole.

LEAD rates highest in corrosion test of waste pipe materials



IN A RECENT TEST of various pipe materials used or suggested for soil, waste and vent lines, conducted under accelerated conditions in Fort Worth, Texas, lead pipe proved to be outstanding, having a relative life expectancy of more than six times that of the next closest material tested.

The test specimens were 2 ft. sections of pipe and conformed to established plumbing size specifications. The samples were placed in a wooden rack which was placed in a manhole carrying the return sludge from the Fort Worth sewage disposal plant's aeration basin. The specimens were kept 18 in. above the water line. Analyses showed the sewage to be alkaline, the condensed moisture on the samples acid and the surrounding atmosphere to contain hydrogen sulphide. Although the conditions of the test — being accelerated — were more stringent than usually found in the plumbing system, all of them are present in the ordinary waste system to a lesser degree.

The duration of the test was one year and the table below shows the corrosion rates of the various pipe materials tested.

CORROSION RATES *Data from "Comparative Corrosion Study of Soil, Waste and Vent Pipe Materials" by John D. Kane, Chief Plumbing Inspector, Dept of Public Works, Fort Worth, Texas, presented at the 1949 Annual Convention of the American Society of Sanitary Engineering.*

MATERIAL	WEIGHT LOSS OZ./SQ. IN./YR.	VOLUME LOSS IN. PENETRATION/YR.
LEAD	0.00167	0.000259
CAST IRON	0.02510	0.005540
BRASS	0.04910	0.009660
GALVANIZED WROUGHT IRON	0.01370	0.003022
GALVANIZED STEEL	0.02160	0.004758
COPPER TUBING TYPE L	0.10150	0.019720
ALUMINUM	0.00270	0.001825

Furthermore, lead was the only metal not affected by pitting. All the other materials were pitted in varying degrees with one of the most commonly used competitive metals having pitted completely through the wall of the tubing.

The results of the test prove conclusively that for the conditions encountered in soil, waste and vent lines, lead is, by far, the most enduring pipe material.

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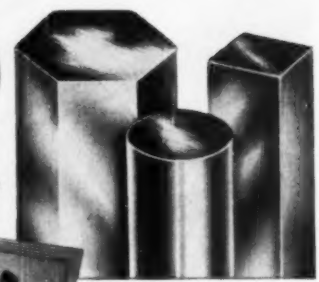
Tough Machining Problems Solved with J&L Cold-Finished

JALCASE 10

J&L STEEL



Maybe you haven't gotten the word yet, but more and more machinists are "discovering" Jalcase 10 (A.I.S.I. No. C-1144), the top grade of J&L Cold-finished Jalcase. And they're getting good results, too! Here's why.

Jalcase 10 is the highest carbon grade of Jalcase; it has high mechanical and machinability properties. This makes Jalcase 10 ideal for those tough "in between" machining applications. For instance:

Many times the finished-parts specifications on a job call for a high degree of hardness, but not as high as that obtained through heat-treating the finished part. In these applications, manufacturers and machinists have found it profitable to use Jalcase 10 and dispense with the heat-treating altogether.

This saves production time and cuts down on costs. And Jalcase 10's high quality produces a better finish. It's worth your while to try Jalcase 10 on your screw machines.

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You'll want more information about Jalcase 10 . . . and the other nine grades of Jalcase. Our booklet entitled "You Can Make Them Better with J & L Cold-finished Jalcase" contains information and technical data to help you produce better parts. This illustrated booklet is yours for the asking. Write today!

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405 Jones & Laughlin Building
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—Please send me a free copy of "You Can Make Them Better with J&L Cold-Finished Jalcase".

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ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

SILICON . . . Deoxidizes, Increases Strength, and Improves Electrical Properties of Metals

Silicon is one of the most important elements used in the iron, steel, and non-ferrous industries. It is an efficient low-cost deoxidizer; and in larger amounts, it is also an effective alloying element.

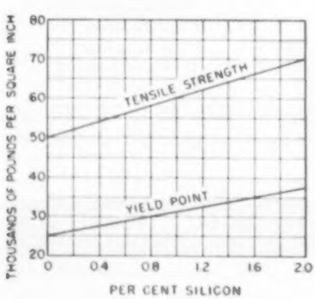
Efficient Deoxidizer

Silicon is used in practically all grades of carbon and alloy steels and offers an economical means of effectively eliminating oxides from the molten bath in all steel-making processes. Amounts up to about 0.80 per cent silicon are used for deoxidizing various steels used for forgings, wrought products, and castings.

Recent published research papers, covering work done in ELECTROMET's laboratories, have added greatly to the knowledge about the deoxidizing power of silicon by itself, and also in conjunction with other elements. Complete information is given in a report entitled "Solubility of Oxygen in Liquid Iron Containing Silicon and Manganese." If you would like a copy of this report, free of charge, write to the address above.

Improves Physical Properties

When used as an alloying element, silicon in small percentages will increase the tensile strength, yield point, and ductility of structural steels, such as those used for highly stressed parts of bridges. Some spring steels contain about 2 per cent silicon. Another application of silicon as an alloying element is in stainless steels, where it appreciably increases the resistance of these steels to certain types of corrosion and to high-temperature oxidation.



Effect of silicon on tensile strength and yield point of a steel containing approximately 0.10 per cent carbon.

Decreases Watt Loss

Silicon increases the magnetic permeability of steel. Hence silicon steel is specially suited for use as a "core" material in electrical generators, motors, transformers, electromagnets, and other electrical equipment. Because silicon decreases magnetic resistance, silicon steels show much lower eddy current losses. As a result, energy or watt losses are greatly decreased and tremendous overall savings are effected in the generation, transmission, and use of electrical power. Up to 5 per cent silicon is used in sheet steel for electrical apparatus.

Benefits Cast Iron

In cast iron, silicon not only serves as a deoxidizer but also has a marked graphitizing effect. Silicon tends to soften cast iron, thereby improving machinability and providing a control over depth of chill and physical properties. In larger amounts, sometimes as much as 14 per cent, silicon makes cast iron suitable for handling highly corrosive acids in chemical plants.

Improves Non-Ferrous Alloys

Silicon is used in non-ferrous alloys to increase strength and hardness, and to improve other physical properties. In various aluminum alloys, as much as 18 per cent silicon may be used. Copper alloys, too, frequently contain silicon: for example, the silicon bronzes.

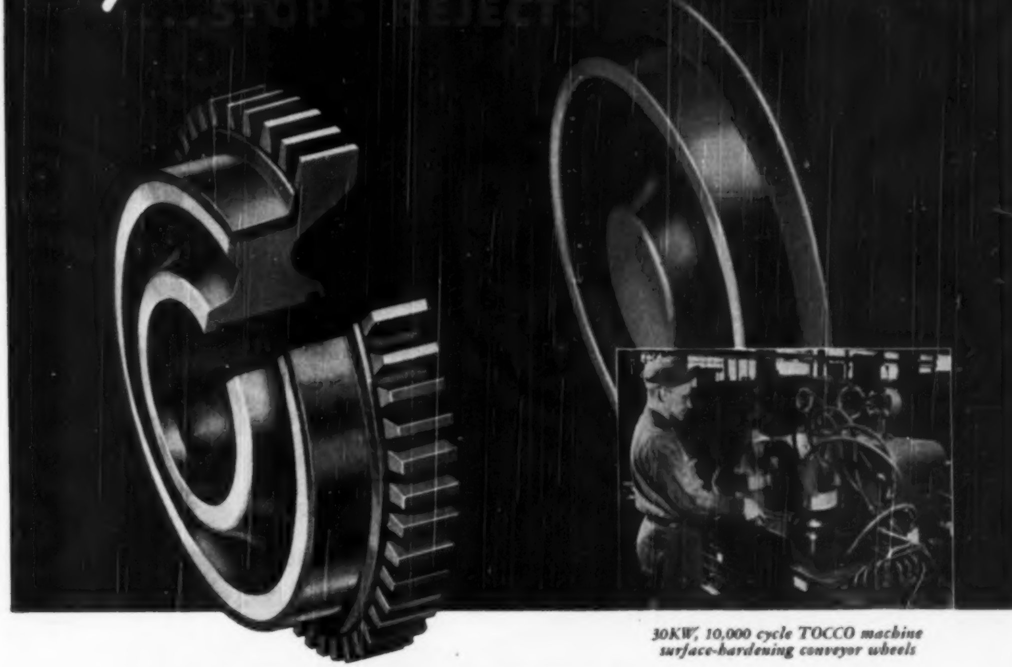
Available Alloys

Silicon is produced by ELECTROMET in the forms listed below, which are suitable for every use of the iron, steel, and non-ferrous metal industry. For a complete description of these alloys, write to the address above for a copy of the 100-page booklet, "ELECTROMET Ferro-Alloys and Metals." This booklet describes over 50 metals and alloys produced by ELECTROMET and tells of the unique technical service offered to the metal industries.

Alloys of Silicon and Their Uses

15% Ferrosilicon	In ground form, this alloy is used in the "sink and float" process of concentrating ores.
50% Ferrosilicon	Widely used as a deoxidizer; as a furnace block; and for adding silicon to fill specifications in the production of steel. Also used in the production of cast iron.
65% Ferrosilicon	Used mainly in the production of electrical sheet steel. (Available in low-aluminum grade only.)
75% Ferrosilicon	Used both as a deoxidizer and for alloying purposes in the production of steel, particularly steel containing high percentages of silicon. Also used for ladle additions to cast iron.
85% Ferrosilicon	Used for same general purposes as 75% ferrosilicon. Permits large silicon additions without harmful chilling effects.
90% Ferrosilicon	Used for same general purposes as 75% and 85% ferrosilicon. Permits large silicon additions without harmful chilling effects.
Silicon Metal	For use in the non-ferrous industry, particularly in the manufacture of aluminum and copper alloys. Also used to produce the organo-silicon compounds known as silicones.
Purified Silicon Metal	For special applications requiring silicon metal of the greatest purity.
"SMZ" Alloy	For ladle additions in the production of cast iron. Exerts strong graphitizing effect.
"ELECTROMET" Special Graphitizer	For ladle additions in the production of cast iron.
"EM" Silicon Briquets	For adding silicon to cast iron in the cupola or air furnace.
Silicomanganese	For adding silicon and manganese simultaneously in steel making processes.

Ups output 250%



30KW, 10,000 cycle TOCCO machine surface-hardening conveyor wheels

with TOCCO* Induction Heating

PROBLEM: Cleveland Crane and Engineering Co. hardens the *running surface* of steel drive wheels and idlers used in their tramrail overhead materials handling equipment. Flame-hardening limited their production to only 300 wheels per day—rejects ran as high as 55%!

SOLUTION: A 30KW, 10,000 cycle TOCCO machine to provide speedy automatic heating.

RESULT: Production increased 250%—costly rejects eliminated, a completely automatic "virtually foolproof" operation. The TOCCO machine, in use for two years, has required no maintenance other than regular lubrication!

Like to duplicate this success story? Why not have a TOCCO engineer survey your hardening, brazing, forging or melting requirements for similar cost-cutting results?

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HIGH FREQUENCY INDUCTION FURNACE lined with Norton RM-1169 Magnorite* cement having a maximum use temperature of 3250°F.

LINED TO LAST AT 3250°F

...*with Norton* MAGNORITE *Cement*

To get more heats out of your high frequency induction furnace linings, try dry-ramming with Norton RM-1169 Magnorite cement. RM-1169 is a result-proved mixture of very coarse electrically fused magnesia grain and enough ceramic binder to give you a dense pack. Maturing at 2100°F, it takes temperatures up to 3250°F in stride. RM-1169 matures in the first heat at the inner edge only. No all-the-way-through cracks to short out your furnace! Easy and inexpensive to install, it also gives you a lining that's easy to patch. It will pay you to make a test run of Norton RM-1169 Magnorite cement next time one of your furnaces needs relining. Order from your nearby Norton refractory distributor. NORTON COMPANY, WORCESTER 6, MASSACHUSETTS.

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"The most helpful bulletin on refractory cements ever published"

That's the opinion of the foundry and furnace men who have read this new Norton bulletin. Compiled after exhaustive laboratory and field tests by Norton refractory engineers, this bulletin covers the entire subject of Norton cements with charts, drawings and detailed instructions.

Selection charts

If this bulletin contained nothing but its two selection charts, it would be well worth sending for. At a glance, you know the right cement for various metal-melting furnaces, for brick laying, for resistor imbedding, for burner blocks and tunnels.

"How To" Instructions

Other subjects covered by this booklet include correct preparation, proper installation, drying and maturing . . . all the do's and don'ts that add up to longer-lasting cement applications.

Write for bulletin 863

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METAL PROGRESS

The Magazine for Metallurgical Engineers

Vol. 58 *November, 1950* *No. 5*

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way protection

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In an article, "Conservation of Columbium", in Metal Progress *for July, John F. Tyrrell urged the rather general substitution of titanium-stabilized steel (Type 321) for the columbium-stabilized grade (Type 347). Here are the reactions of 56 British and American metallurgists from all industries concerned. Besides comment on Mr. Tyrrell's main thesis, the discussion includes other closely related matters not dealt with in the original article — for instance, the use of stabilized steels in the chemical industries.*

Conservation of Columbium

A Summary of British and American Experience With Stabilized Stainless Steels

"When in Doubt . . ."

JEANNETTE, PA.

We believe that Mr. Tyrrell has done the country a real service by bringing the long-standing controversy between Types 321 and 347 out in the open. We have largely been guilty of the policy: "When in doubt, specify 18-8 columbium". Mr. Tyrrell makes it obvious that at least where sheet products are concerned, we should not be in doubt about the over-all serviceability of 18-8 titanium.

The big problems with the titanium-bearing steels have been cleanliness and quality. Solar's experience demonstrates that these problems have been solved for sheet products, at least by some suppliers.

C. T. EVANS, JR.
Chief Metallurgist
Elliott Co.

Supply Situation

PITTSBURGH

Mr. Tyrrell's article is not only of considerable interest to users and makers of stainless steel, but also is unusually timely. We who manufacture stainless and heat resisting alloys have long been concerned about alloy conservation, which is so vital to our national security. In the few short years since World War II, the consumption of steels containing large quantities of chromium, nickel, tungsten, cobalt and columbium has increased tremendously. This puts a strain on the facilities which produce such raw materials to the extent that they cannot always meet the demands imposed on them. The result is a shortage of high-alloy steels, even though the actual steelmaking capacity is adequate. However, this is not nearly so serious a condition as allowing ourselves to become dependent on metals or ferro-alloys which might suddenly become practically unavailable in an emergency.

In his article, Mr. Tyrrell has contributed knowledge gained over a period of years in the production of "more than 400,000 exhaust manifold sets for aircraft engines". The data obtained from such extensive experience certainly should command the attention of all production-minded engineers. Too often our decisions as to the use of high-alloy materials must be based on the results of isolated laboratory tests which do not always duplicate anticipated service conditions. In this instance, we are assured that, using proper production techniques, Type 321 steel can be formed, welded and used without difficulty.

The important question to be answered in considering steel applications is not, "How much better is Type A than Type B?" but rather, "Which steel will provide the required properties at minimum cost per fabricated unit?"

From the standpoint of the steelmaker, our chief interest lies in our ability to supply the needed materials. With respect to the stainless steels under discussion, manufacture presents no unusual problems, and

> ***BULLETIN***
>
> WASHINGTON, Oct. 19 — The entire production and use of columbium-bearing stainless steels will be reserved for defense needs under an order issued today by the National Production Authority. The order, NPA Order M-3, prohibits the use of ferrocolumbium-bearing steels or ferrotantalum-columbium-bearing steels where any other substitutes can be used.

we are limited within present capacities only by the availability of the alloying elements involved.

D. W. Kaufmann
Metallurgist
Crucible Steel Co. of America

British Aircraft

Farnborough, England

Broadly speaking, our experience in this country confirms Mr. Tyrrell's recommendations and suggests that further efforts toward columbium conservation would be worthwhile. The use of columbium for aircraft purposes falls into two categories: *(a)* high-temperature materials of the so-called superalloy type, and *(b)* general-purpose austenitic steels of the 18-8 type.

Considering high-temperature materials first, the best turbine blading alloys and some of the best disk alloys in the U. S. have been columbium-bearing, whereas in the U. K. columbium has never found much application in blading material but has been used extensively in disks. Our practice has been due to the experience that the columbium-bearing alloys have remarkable casting and forging properties so that large masses can be produced with great reliability. The titanium-bearing alloys can be produced best in small masses suitable for blading. At every stage of engine and alloy development there has been a titanium-bearing material with properties equivalent to the columbium-bearing alloy, but these have not been used in large forgings because of production difficulties. Production rates might well be a dominant factor in wartime and would suggest that an addition to the present extensive research into production methods would be desirable. Even so, although the production and use of titanium-bearing alloys might be extended, it will be a long time before they are made as readily as current columbium-bearing alloys.

Turning to the 18-8 type of material, the same considerations apply but to a lesser extent. Generally, better and cleaner ingots are more readily produced with columbium than with titanium, but no real difficulty is found with the latter. Production of 18-8Ti in this country has always been much more extensive than production of 18-8Cb — to such an extent that 18-8Ti can properly be regarded as the standard welding quality of 18-8. Large quantities of this material have been used successfully for components such as engine exhaust manifolds or the sheet metal parts of turbines. The advantages of using 18-8Cb in aircraft appear to be in the production of intricate castings and in having a more pleasing appearance in the surface of highly polished sheet. These seem slight advantages to offset against the objections which can be raised to its uses.

The situation has now been reached when columbium is being recognized for what it is — a relatively rare metal. It is likely to become progressively less readily available, and even if available its price must almost certainly increase substantially. Economic factors will therefore operate tending to increase efforts to devise effective substitutes, but some of these will require extensive research and may take considerable time. In the meantime, as Mr. Tyrrell shows, an effective substitute is already available in certain fields of application, while in others columbium has distinct advantages and no replacement is possible. It would be a praiseworthy act of self-discipline if manufacturers could reach agreement in limiting the use of columbium to essential applications, and at the same time initiate the research, possibly on a cooperative basis, necessary for extending the use of substitute materials.

L. Rotherham
Head of Metallurgical Division
Royal Aircraft Establishment

Hayes, England

This country has many years' successful experience of the reliability of titanium-stabilized steels to support Mr. Tyrrell's recommendation. Application of austenitic stainless steel in British aircraft is usually restricted to *(a)* parts requiring heat resistance, including strength at elevated temperatures, *(b)* where cadmium-plated ordinary steel is unsuitable, and *(c)* where nonmagnetic properties are essential. For upwards of 20 years, all austenitic stainless steels used in the British aircraft industry (18-8 and the later 23-14 and 23-18 heat resisting types) have been stabilized, to pass the weld decay test. It is probably safe to say that well over 90% of these steels have been stabilized with titanium.

In the main, it is difficult to discriminate between titanium-stabilized steels and columbium-stabilized steels for ordinary purposes but, on account of the increased cost of the required columbium addition, the use of columbium (which has shown no apparent advantages) has not found favor for the general constructional varieties.

In certain instances, however, we have found that columbium has advantages: It is standard practice to use columbium in place of titanium in electrodes. It is also found that columbium-treated steel can be given a much more highly polished finish than a corresponding titanium-treated steel, which may contain titanium inclusions. However, the tonnage of columbium-treated material is small.

With regard to the comparison of the properties of titanium and columbium-stabilized steels for high-temperature purposes, as for turbine blades in jet engines, while individual investigators appear to have noted differences in the high-temperature properties (for example, creep), it is not altogether certain that the differences found are attributable to the type of stabilizing element, as the basic composition and structure of the material can be much more influential. Therefore, it is the *general* opinion that any differences between columbium and titanium steels are only slight.

W. E. Cooper
Chief Metallurgist
Fairey Aviation Co., Ltd.

Editor's Note: The writer of the above letter, Mr. W. E. Cooper, has been chairman of the Materials Committee of the British aircraft industry for more than eight years. During the last war, he was actively concerned with the U. S. and British Commonwealth Aircraft Interchangeability Schedule, which was subsequently published as S.A.E. Aeronautical Information Note No. 8.

Is Stabilization Necessary?

Bartlesville, Okla.

The oil industry uses large tonnages of 18-8 and other austenitic steels in gas cracking and in still tubes. Many of these installations are of welded construction. Metal temperatures are generally in the carbide precipitation range during operation. Therefore, it was originally believed necessary to use stabilized grades.

Operating experience showed that the inside of the tubes became carburized in service. Because of the increase in carbon content, there was not sufficient columbium or

Fig. 2 — Failure in Corroded Turbosupercharger Nozzle Boxes From a B-24 Airplane. Steel is unstabilized Type 316

titanium present to keep the metal stabilized. If the tubes do not remain stabilized in service, why use stabilized steel in the first place? Most installations are now made with ordinary 18-8 and other unstabilized austenitic steels, and the performance has been entirely satisfactory. There are other applications of welded austenitic steels that do not require the stabilized grades even though they operate in the carbide precipitation range. Is it possible that the aircraft exhaust manifold is such an application?

M. E. HOLMBERG
Phillips Petroleum Co.

American Aircraft

DAYTON, OHIO

The exhaust equipment for aircraft engines was first manufactured from low-carbon steel, but corrosion and low mechanical strength at operating temperatures led to the introduction of 18-8 stainless steels. The unstabilized stainless proved unsatisfactory due to a combination of operating stresses and corrosion in those portions of the manifolds which were subjected to high flame temperatures. (The accompanying illustration shows a characteristic service failure that occurred near a welded seam in an exhaust manifold made of unstabilized material; the micrographs indicate the type and extent of corrosion on specimens taken adjacent to the crack.) It was also very difficult to clean the equipment on overhaul, except by pickling, which causes embrittlement of the unstabilized material.

The use of stabilized stainless steel since the early 1930's has practically eliminated all failures, except those due to design and faulty installation. More recently, after an epidemic of failures, it has been found necessary to change to a stabilized material in superchargers, due to the rapid corrosion and embrittlement of unstabilized Type 316.

The problem of selecting the correct steel for application at elevated temperatures is never simple, because the operating conditions are often not completely known or controllable. The selection is normally made on the basis of engineering properties, previous experience, and economics. The engineer is reluctant to change a material that has given satisfactory service. Failures during operation sometimes compel it.

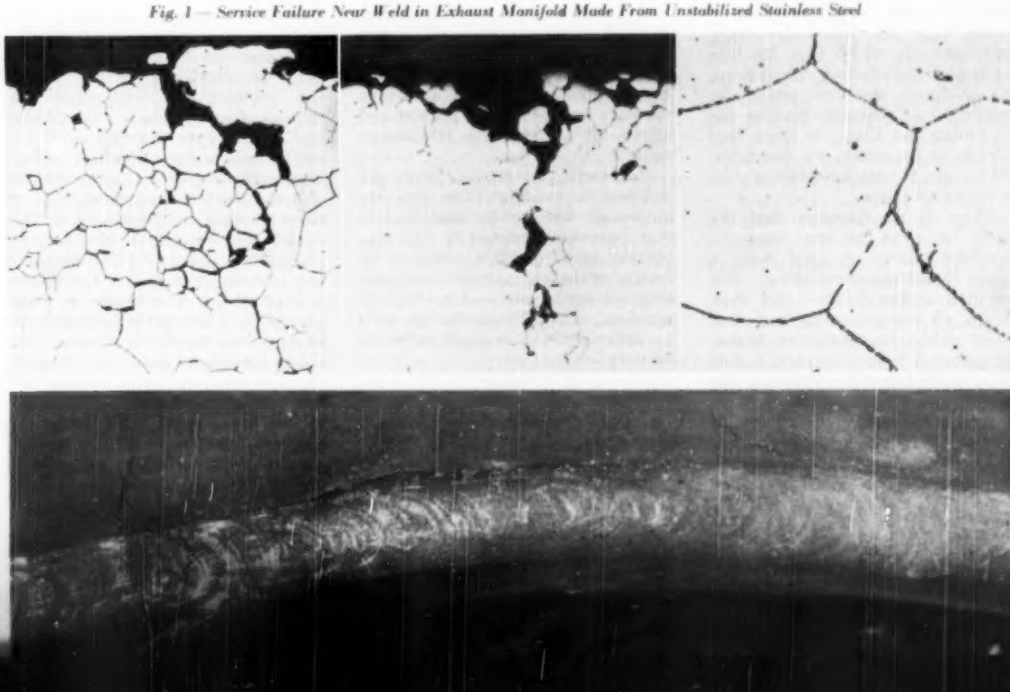
In general, the service life and the character and frequency of repairs on aircraft components are influenced to a much greater extent by design and installation than by small differences in the properties of the materials. Several years of operating experience with equipment fabricated from both grades of stabilized stainless steel have not indicated any preference or advantage for either Type 321 or 347. However, columbium has always been an element available only in limited amounts, due to the scarcity of the known ore supplies, and it is therefore essential that columbium be conserved. A practical approach to conservation is to encourage the use of Type 321 steel for the components referred to by Mr. Tyrrell.

J. B. JOHNSON
Chief, Metallurgy Group
Office of Air Research

ST. LOUIS

The use of both Types 321 and 347 stainless steels in aircraft components has been a practice of long standing. There seems never to have been a logical reason for using 347 in these applications except for the fact that at certain times it was more readily available than 321. This, no doubt, can be accounted for by the fact that 347 is more

Fig. 1 — Service Failure Near Weld in Exhaust Manifold Made From Unstabilized Stainless Steel



widely used in the chemical industry, particularly to resist nitric acid. Since there was little or no difference between 321 and 347, with respect to mechanical properties, the use of 347 was attempted. In most parts, Type 347 was suitable except in some isolated instances where deep draws were required. For these reasons, 347 was accepted as an alternate for 321, even though it was generally somewhat more expensive. Our experience with using the two materials indicates that either is equally suited to use in aircraft components. Primarily because the need has not arisen heretofore, no attempt has been made to standardize on either type of stabilized steel.

In order to assist in conserving columbium, this company now proposes to specify Type 321 titanium-stabilized 18-8 stainless steel on all new designs which require corrosion resistance and heat resistance and also to analyze its present usage of Type 347 columbium-stabilized 18-8 with the purpose in mind of replacing all 347 with 321. A recent preliminary survey of this problem indicates that 347 can be replaced with 321, thereby conserving considerable quantities of columbium, nickel and manganese.

L. H. McCreery
Metallurgist
McDonnell Aircraft Corp.

Wood-Ridge, N. J.

We have used both columbium-stabilized and titanium-stabilized steels, but have specified Type 347 for some parts made from tubing, not because of stabilization, but because of seams caused by titanium in the Type 321. There are many applications in which Type 321 tubing is quite satisfactory when properly produced. However, one of our suppliers had difficulty making the 321 tubing and since we knew that it tends to be seamy, we discontinued the use of titanium-bearing steel on thin-wall parts.

There is no question that the seams in some of the titanium-stabilized tubing we used were a source of mechanical weakness. We first had engine failures and then set up an inspection method that would detect the defective tubing and permit it to be separated. Later, we concluded that discontinuing the use of Type 321 tubing was a safer procedure for the aircraft parts in question.

Our application was fuel-injection lines operating at low temperature and the only reason for stabilizing was to prevent carbide precipitation during brazing. After first changing to the columbium type, we subsequently adopted unstabilized 18-8 of low carbon content, because the producers stated that manufacturing procedures were simplified when no columbium was used.

B. Clements
Metallurgical Engineer
Wright Aeronautical Corp.

Los Angeles

Although there may be differences of opinion concerning the proper stabilizing agent for 18-8, there can be no argument about the columbium supply situation — there is a serious shortage in supply.

Among the aircraft applications of stabilized 18-8 mentioned in Mr. Tyrrell's article, one of the most demanding has been exhaust collectors, which generally operate with high pulsating stress at about 1200° F. For such components, even small differences in design are sufficient to mask any effect from differences in material that might otherwise be noticeable. North American Aviation, Inc., has had no opportunity to compare service performance of 321 with 347 in *identical* design. Our experience with designs that are similar but not identical indicates no significant difference in service performance between 321 and 347. Because 347 uses the more strategic columbium and is more costly than 321, we prefer 321. Problems of ready availability have often dictated the use of 347 interchangeably with 321.

We have found no real difference in the forming properties of 321 and 347 which could be attributed to the stabilizing element, and we feel that any difference which might exist is masked by the more pronounced effects of tooling and fabrication method.

Similarly, neither alloy poses any problem in welding. The only requirement we consider necessary is that columbium should be the stabilizing agent in filler rod used in fusion welding. If an inert-gas-shielded arc is used and no filler is required, as in a "flange burndown", no differentiation is made between the two steels.

R. R. Janssen
Material and Process Engineer
L. P. Spalding
Director of Research
F. B. Bolte
Assistant Chief Research Engineer
North American Aviation, Inc.

Seattle, Wash.

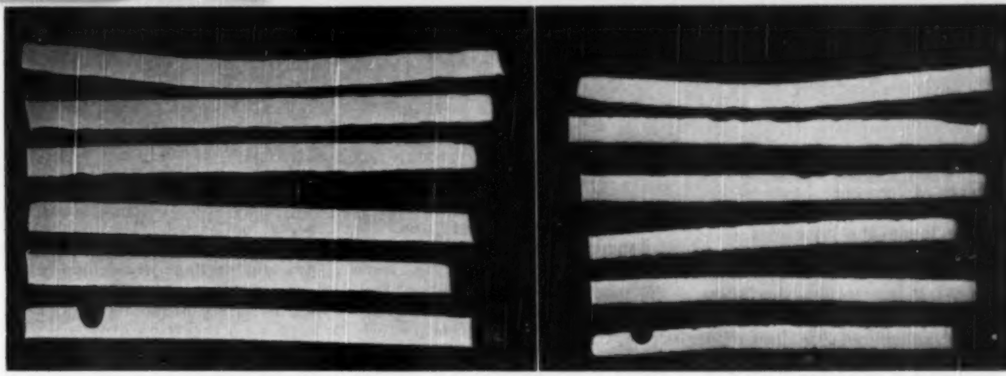
It has been our experience that Types 321 and 347 can be used interchangeably for aircraft applications and we so specify on our drawings. We actually purchase considerably more 321 than 347 because of its lower price and generally increased availability.

Types 321 and 347 were used interchangeably on the B-17 and B-29 airplanes. They were used in all applications where stainless steel was assembled by welding. The welding was done with columbium-stabilized rod and no difficulty was experienced with Type 321.

Other applications for these steels were where the temperature was to be in excess of 800° F. This included the exhaust system and shrouding of some areas of the exhaust system. Service experience has shown 321 to be satisfactory when operating below 1500° F.

The reciprocating engines now being used on larger aircraft are developing exhaust gas temperatures in the vicinity of 1850° F., and the exhaust stack material must give a satisfactory operating life. The effect of temperature on the properties of various heat resistant materials when tested in air at service temperatures is available, but this is not the controlling factor. The corrosion plus high-temperature oxidation and erosion effect of the service environment are the predominating factors.

We have used a cyclic test to evaluate several materials for actual service tests. This laboratory test was developed by the General Electric Co. to simulate service conditions (see *Iron Age*, March 6, 1947). The test attempts to follow the cycle of actual operation in which the products of combustion are deposited on the stack wall. When the engines are stopped and the stacks cool, water condenses on the walls. The engines are again started and the stack temperatures rise to the operating temperature. In the cyclic test a sample of metal is placed in a 250-ml. beaker containing 150 ml. of distilled water and 5 g. of $PbBr_2$. The beaker is then placed on a hot plate and allowed to evaporate slowly to dryness and baked for 5 to 10 min. The temperature of the solution is maintained between 140 and 160° F. and 12 to 16 hr. are required for complete evaporation. The solution is stirred approximately every 2 hr. After baking, the dry piece is placed in



Titanium-Stabilized Steel (Type 321)　　　Columbium-Stabilized Steel (Type 347)

Specimens Tested for Susceptibility to Lead Bromide Attack at High Temperature (John W. Sweet)

a shallow quartz boat and heated 1 hr. in a furnace at an elevated temperature representative of service temperature and allowed to cool in air; then distilled water is added and the complete cycle is repeated twice. The accompanying illustrations show representative cross sections of 321 and 347 tested in this manner. The three specimens on the lower half of each macrograph were cycled to 1200° F. and the three on the upper half were cycled to 1500° F. This indicates superiority of Type 321 when subject to lead bromide attack under the test conditions.

It is our opinion that service tests or simulated service tests are the only satisfactory means of comparing different alloy compositions and of assuring satisfactory service from materials used for exhaust stacks of reciprocating engines used on the larger aircraft. The high temperatures, in conjunction with stresses, leaded fuel and other operating factors, result in conditions that cannot be duplicated in standard test procedures.

JOHN W. SWEET
Chief Metallurgist
Boeing Airplane Co.

HAWTHORNE, CALIF.

Mr. Tyrrell's remark that the columbium in Type 347 *prevents* carbide precipitation during exposure in the sensitizing range of temperatures is in my opinion subject to review. "Substantially reduces" might be a better expression.

In my opinion his demonstration of the superior formability of 321 over 347 is corollary with the increased hardening effect of columbium compared to titanium, and also the slight advantage of 347 over 321 in terms of creep strength above 1000° F. This latter point is more academic than significant to aircraft design. Northrop Aircraft, Inc., has established equivalence for most applications, especially in the moderate temperatures below 800° F.

The welding technique is believed to be more critical with 321 than 347 because of the questionable replacement, completely, of titanium-starved areas. For that reason extreme care is exercised by us in the use of columbium-rich metallic arc rod for welding 321.

K. F. FINLAY
Metallurgist
Process Engineering Dept.
Northrop Aircraft, Inc.

EAST HARTFORD, CONN.

Our use of the two grades of stabilized stainless steel has been for jet engine components and has been quite limited, since the majority of the sheet metal parts require the maximum resistance to oxidation and corrosion that is attainable. For this reason, 25-20 Cr-Ni steel or alloys of the Inconel type are finding wider application.

Except for special purposes or to facilitate certain processing procedures, it is my opinion that Types 347 and 321 are equivalent and that for the majority of applications either grade can be successfully employed. There are a few instances where we feel the somewhat higher creep strength obtainable with 347 is an advantage. Also, we have found that 347 is superior where silver or copper brazing is specified, since 347 is more easily wetted and gives off less gas at the brazing temperatures than does 321. Where resistance welding is specified, the titanium grade seems to offer an advantage. For fusion welding, either grade is satisfactory, but the columbium-stabilized welding rod is specified.

In my opinion, the strongest argument for 347 over 321 is that it is more uniform; also, it is usually cleaner. Once the melting problem is overcome, the biggest handicap associated with the 321 grade, in my opinion, will have been solved.

R. H. THIELEMANN
Development Metallurgist
Pratt & Whitney Aircraft

WEST LYNN, MASS.

General Electric's experience has been primarily with Type 347 stainless steel. This was originally chosen because of slightly higher creep and rupture strength, superior welding characteristics using the atomic hydrogen process (which was in wide use at that time), and lower susceptibility to intergranular corrosion in the Strauss test. With the shortage of ferrocolumbium, considerable effort has been made to replace the columbium-stabilized steel with the titanium grade (Type 321) and with appreciable success.

The chief disadvantage with Type 321 is the difficulty it presents in welding with the atomic hydrogen process. In the last few years, there has been a shift from the atomic hydrogen process to the inert-gas-shielded arc process; however, there still remain numerous applications for the atomic hydrogen process. The trouble lies in the formation of a scum which makes atomic hydrogen welding slow, difficult, and of poor appearance.

Also, 321 has been difficult to produce with a surface quality comparable to 347. This is of considerable importance in some parts that are subject to fatigue stresses.

Welding experience with the inert arc, metal arc and resistance techniques substantiates the work done by Mr. Tyrrell. Type 321 offers a definite advantage over 347 in the inert-gas-shielded arc process, as it is apparently not so subject to weld cracking when the joint is made at high speeds.

No difference has been observed

between 321 and 347 in the various methods of forming. Shop procedures have not been changed other than to lower the annealing temperature to 1800° F. for 321.

With regard to stabilization of Type 321, it appears that the industry-wide standard, requiring a titanium content of five times the carbon content, is too low, and that a minimum of six times carbon is desirable. This fact has been noted in laboratory examination of various heats and is substantiated in publications by S. J. Rosenberg of the Bureau of Standards. (See, for instance, "Stabilization of Austenitic Stainless Steel", *Transactions*, American Society for Metals, Vol. 41, 1949, p. 1261.)

Another possible solution to the program to conserve columbium is the use of somewhat more available ferrotantalum-columbium to stabilize the austenitic stainless steel. Tests are in progress on several heats with varying ratios of columbium plus tantalum to carbon. There seems to be very little difference between the corrosion characteristics of these alloys and the regular Type 347. The ratio of columbium plus tantalum to carbon has to be about 11 minimum for complete immunity to intergranular attack.

The mechanical properties of the alloys containing both tantalum and columbium are comparable with Type 347, with the possibility of slightly higher stress-rupture strength at 1200° F. In some instances, the rupture ductility has been lower than anticipated or desired. However, with the accumulation of data it appears that the range of rupture ductility will be about the same as for Type 347.

In laboratory welding tests (atomic hydrogen, metal arc, inert arc, resistance), the 347 Ta-Cb alloys weld in a manner comparable with the regular 347.

With the present critical shortage of ferrocolumbium, it is apparent that the available supply will be diverted to the high-temperature alloys which require the columbium to gain their high strength. This means that the users of 347 steel will have to choose an alternate in either 347 Ta-Cb or 321. All things being considered, it appears that the better choice in the long run is Type 321.

W. E. Jones
Thomson Laboratory
General Electric Co.

Stabilized Stainless in the Chemical Industries

Wilmington, Del.

Mr. Tyrrell's informative article serves well in pointing up some pertinent factors in the current outlook for the economy of columbium. The rigid allocation of this strategic alloying additive during World War II forced economies and general substitutions in plant equipment construction which in many cases were abandoned as soon as the emergency was past.

Agreement, in general, can be found with much of the physical data and process information presented in this comparison of materials for aircraft services in which high operating temperatures are encountered. The replacement of columbium by the more readily available titanium stabilizing agent in stainless alloys for severe chemical plant service is not so clearly defined from practical considerations as was reported in this study of aircraft applications.

When it comes specifically to selecting a stabilizing agent for stainless steel in extremely corrosive service, there has been and still is a difference of opinion as to the reliability of titanium versus columbium. We have had good performance from both materials in some services. However, in the most critical applications, particularly those processes using hot nitric acid — one was of the greatest strategic importance — the judicious use of columbium in a properly balanced alloy shows an advantage over titanium as a stabilizer.

By way of individual experience, we have been making impartial reappraisals of old and new specifications and recommendations. In more than a few cases, we are building plant extensions from Type ELC 304 and conventional Type 304 where there is reasonable indication that the stabilized grade used in the semiworks or in some of the initial plants was not actually necessary. Equipment design limitations and also conditions for fabrication in the field must not be lost sight of in any calculated substitutions of Type 304 for either 321 or 347.

The use of stabilized austenitic castings warrants a brief reference. The frequently observed greater loss of titanium over columbium during melting has long been accepted as factual. The fabrication of weldments in which castings and wrought sections are joined without subsequent heat treatment for use in severe nitric acid corrosion presents a recurring problem, with the present solution to it calling for stainless steel castings stabilized with columbium.

It is at once recognized that there are hundreds or even thousands of plant corrosive service conditions ranging from the mildest noncorrosive service to the most severe where equipment life is recorded in weeks or even days. All along this graduated scale of increasingly severe service conditions competent opinion will likely vary. Each one may be satisfied for a time with his own answer. Current discussion of the conservation of columbium will have served a useful purpose if it stimulates a revival of thinking and experimentation on this subject and thereby encourages engineers responsible for the selection of materials to make impartial and rigid reappraisal of their needs.

H. L. Maxwell
Supervisor of General Consultants
Engineering Dept.
E. I. du Pont de Nemours & Co.

Nitric Acid Service in Britain

Billingham, England

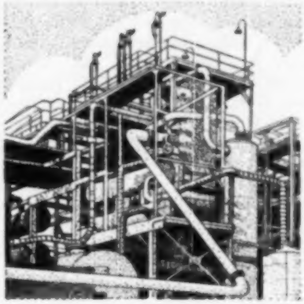
I have read with very great interest the article by Mr. John F. Tyrrell in the July issue of *Metal Progress*. The facts and experience which Mr. Tyrrell recounts are in a different field of activity from those dealt with in my article of December 1948,* and are therefore directly additive to the weight of evidence already produced for reconsideration of the position of columbium as a stabilizing element.

*Editor's Note: The article referred to, "The Austenitic Stainless Steels — American and British Practice Compared" (*Metal Progress* for December 1948), includes a column of discussion under the heading *Titanium or Columbium for Stabilization?* which concludes with this prophetic sentence: "It may be well to ask whether the long-term view would not be to encourage the use of the element [titanium] that has given good performance over a period of years and that is in abundant supply in the earth's crust, rather than a material [columbium] that may become scarce."

In one part of his article, Mr. Tyrrell does deal with the chemical industries and makes a statement which would indicate that Type 321 stainless steel has poor resistance to nitric acid. The statement is a general one, and would give the impression that Type 321 should not be considered for nitric acid plant construction. In the writer's experience, this statement is entirely misleading and is probably another product of the widespread misuse of the boiling nitric acid test [Huey test] as a general assessment test. It is a fact that many nitric acid plants in this country are constructed entirely of Type 321 steel and have given complete satisfaction for many years. The only single application on straight nitric acid duty in which the writer has found Type 347 steel to be superior to Type 321 is in the storage of acid of 95% concentration. Even in this use, the Type 321 steel fails not by general corrosion but by channelling attack on a narrow zone immediately adjacent to the weld. Type 347 steel is entirely immune to this type of attack. Initial studies indicate, however, that it is not impossible that a solution to the problem of attack on the titanium-stabilized steel may be found other than the substitution of columbium-stabilized steel. It can be shown that the attack results from the structural rearrangement resulting from heating the steel in a narrow range close to the fusion range. It is possible that the troublesome structure in the susceptible narrow zone can be controlled by diffusion from a carefully selected electrode composition. Even if no specific solution is forthcoming, however, it is important to note that a few isolated cases of this kind do not give a logical basis for rejecting Type 321 steel entirely for nitric acid duty.

Apart from the economics of the situation, which Mr. Tyrrell mentions, it would appear that scarcity exaggerated by demands for military equipment may force a reassessment of the uses of columbium in all industries. So far as the chemical industries are concerned, the writer is convinced that a considerable portion of its requirements can satisfactorily be met by the use of titanium-stabilized steel.

F. H. Keating
Chief Metallurgist
Billingham Division
Imperial Chemical Industries, Ltd.



Nitric Acid Service in Kansas

Pittsburg, Kan.

Mr. Tyrrell's article on the use of Type 321 stainless steel is most certainly of interest, coming as it has at a time when columbium is in such great demand and short supply. The fact that Solar Aircraft Co. has for some time been using 321 by choice when 347 was available, is a significant point that should not be overlooked by the various fabricators in this country who have been automatically specifying 347 on the assumption that it is superior.

A reference is made in Mr. Tyrrell's article to the effect that Type 321 steel is not satisfactory from the standpoint of chemical corrosion — particularly in nitric acid. I believe that this statement is incorrect or, at any rate, misleading. Spencer Chemical Co. owns and operates a large nitric acid plant producing more than 400 tons per day of 100% equivalent, 55% nitric acid and many of the materials of construction in contact with the acid are fabricated from Type 321 steel. In this category can be named nitric acid heaters, condensers, oxidizers, storage tanks, absorption drums and cooling coils. The only weak point where corrosion has been evident in the system has been around one particular tube sheet where hot gases at approximately 700° F. come in contact with condenser tubes. Replacement tubes fabricated from 347 steel showed absolutely no improvement over 321. However, when these tubes were replaced with low-carbon Type 304 (0.03% max.), they operated a great deal more satisfactorily than when 321 or 347 was used.

R. F. Brown
Chief Engineer
Spencer Chemical Co.

Soap Chemicals

Cincinnati, Ohio

A considerable amount of Type 347 has been used for handling fatty acids and some inorganic acids because of slightly better corrosion rates than with Type 321 and a minimum loss of columbium due to welding. However, our plant corrosion tests in fatty acids (both liquid and vapor) show satisfactory rates for both 321 and 347.* Specimens of 321 were welded with both 321 and 347, and tests were made with sensitized and unsensitized specimens. Corrosion rates were slightly higher for 321 but were well within satisfactory limits for service conditions.

General corrosion and pitting are usually important considerations in chemical process equipment made from a stabilized steel, and we have found these more sensitive to the fabricating processes and heat treatment than to the type of stabilizer.

There seems to be a similar situation in "Type 318" alloy† [0.08% C max., 17 to 19% Cr, 13 to 15% Ni, 2 to 3% Mo, stabilized with 0.50 to 1.00% Cb] and the Firth-Vickers FMB-3T or Brown Bayley BB-4K, which are molybdenum-containing steels stabilized with titanium. Satisfactory rates have been obtained with the latter two steels in service tests with fatty acids and mixtures of inorganic acids and fatty alcohols. However, in nitric acid tests of both sensitized and unsensitized specimens, Type 318 has a lower loss than the titanium-stabilized steels with molybdenum. Strauss tests were satisfactory with both.

As with Types 321 and 347, corrosion rates of Type 318 and the molybdenum-titanium stabilized alloys seem to be more sensitive to fabrication methods than to titanium or columbium as stabilizers.

G. F. Lockeman
Engineering Division
The Procter & Gamble Co.

*Editor's Note: Similar plant corrosion tests have been reported by George F. Comstock (A.S.T.M. Special Publication No. 93, 1950, p. 200). Based on weight loss measurements, his results may be summarized as follows: No difference between 321 and 347 (all specimens completely resistant) in alum, fatty acids and 40% nitric acid solutions. Type 347 slightly better than 321 in 99% sulphuric acid and in fatty acids and fatty acid derivatives such as nitriles and amines. Type 321 slightly better than 347 in acid inorganic sulphates and in sulphite plus sulphur dioxide.

†Not a standard A.I.S.I. type.

Prevention of Carbide Precipitation

ROCHESTER, N. Y.

Although we use considerable quantities of stainless steel in contact with corrosive chemical solutions, most of these applications are satisfactorily filled by Type 304 or 316. We use very little stabilized material. Most of our chemical equipment is constructed from light-gage sheet (up to and including 3/16 in.), and deleterious carbide precipitation is prevented by water cooling the steel during welding.

H. H. BROWN
Metallurgical Laboratory
Eastman Kodak Co.

More Chemical Application

SHEFFIELD, ENGLAND

Mr. Tyrrell's article states very fairly the case for the titanium-stabilized steels, such as A.I.S.I. Type 321, and most British metallurgists would agree generally with the findings. However, the reference to the "relatively low resistance to corrosion [of Type 321] in specific chemical mediums such as nitric acid" is apt to give an unduly pessimistic impression. Nitric acid is the main medium where trouble may be encountered, but neither Type 321 nor Type 347 is suitable for continuous service in boiling concentrated nitric acid. The accompanying photograph shows a portion of a nitric acid plant made in 1931 from titanium-stabilized 18-8 ("Staybrite F.D.P."). So far as I am aware, it is still functioning. The particular illustration is of the oxidizer cooler, but considerable quantities of the steel were also used for other items of plant such as concentrating columns and storage tanks.

As steelmakers, we cannot go into detail regarding the chemical processes for which the steel in question is being used here. However, a few applications may be referred to in which the titanium-stabilized steel (our F.D.P. grade) has proved satisfactory over a long period of years.

Preparation and Storage of Fine Chemicals — One large firm in this country installed various types of chemical plant and storage vessels (for fine chemicals and pharmaceutical products) involving many tons of F.D.P. in their new factory in 1933. This plant is still giving very satisfactory service. While the majority of the plant is in F.D.P. steel, it was necessary of course for some applications to use the molybdenum-bearing F.M.B. steel. (Standard F.M.B. is not stabilized; there is a smaller demand for a type of F.M.B. with about 0.3% Ti.)

Textile Processing and Dyeing — A very large tonnage of F.D.P. steel has gone into the textile industry. Among other applications may be mentioned wool scouring plant, callender rolls and dyeing machines. Again, although F.D.P. has hitherto been the standard material for dyeing plant, there is now a gradual change-over to the molybdenum-bearing F.M.B. type where higher intrinsic corrosion resistance is required.

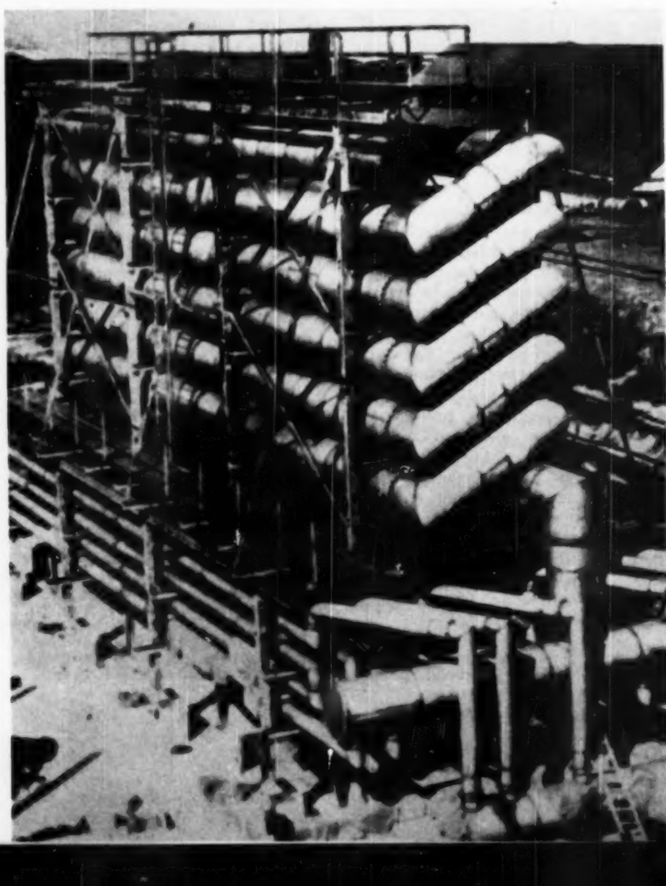
Dyestuffs — Apart from the process of dyeing, considerable quantities of F.D.P. are used in plant for the preparation of the dyes.

Foodstuffs — The dairy industry in particular makes extensive use of F.D.P. for many purposes such as plant for the production of evaporated milk and milk powder. It is also used for the more general applications such as rail and road transport tanks, pasteurizers, separators, coolers, cheese vats, cream cans and general dairy equipment.

Explosives — The titanium-bearing steels have proved over the years to be very satisfactory for resisting mixtures of nitric and sulphuric acid and have therefore been used extensively in nitration processes for explosives.

Cartridge Case Pickling — During the last war a considerable tonnage of the F.D.P. type of steel was used in plant for the pickling of brass cartridge cases. The strength of sulphuric acid used was higher than the steel would normally withstand. However, an addition of up to 1% of copper sulphate to a new solution inhibited attack and very satisfactory results were obtained.

The comparisons between 321 and 347 steels as regards welding and forming are interesting. Similar careful direct comparisons have not, so far as we are aware, been made in this country, primarily because the large majority of steel



Oxidizer Cooler at the Nitric Acid Plant of African Explosives & Industries, Ltd., South Africa. Constructed from titanium-stabilized steel in 1931

supplied for aircraft work is stabilized with titanium. During the late war my company produced a very large tonnage of the titanium-stabilized steel for use in aero exhaust manifolds, which gave very satisfactory service.

With regard to the effect of silicon content on the weldability of 321 steel by the oxy-acetylene process, it is not our practice to have silicon contents less than 0.5% — they generally lie between 0.5 and 0.8%. It is, of course, the general custom that columbium-stabilized filler wire or electrodes be used for the titanium-bearing steels and generally speaking it is considered that little, if any, difference exists in the weldability of the two types of steel. One feature which might be mentioned in connection with the oxy-acetylene welding of these steels is that better and smoother penetration is generally obtained with the titanium-bearing steels than with the columbium-bearing steels. This is because the somewhat more pasty nature of the molten metal produces a smoother underside of the welded joint.

It is interesting to note from the article that the titanium-bearing steel has somewhat better forming characteristics than the columbium-bearing steel. The general experience in this country is that the two steels are similar in this respect, but here again a careful comparison has probably not been made.

The presence of titanium-bearing inclusions, however, which are a characteristic of the titanium-bearing steels, and which often take the form of "stringers", can be detrimental in certain circumstances. Although no particular trouble from this cause has been experienced in drawing operations, these stringers can be troublesome when upsetting operations, either hot or cold, are involved on bar material. These stringers are apt to give rise to splitting in the upended portions of the bar, and for such applications we prefer to use the columbium-bearing steel.

The subject of creep is an important one and has many facets. The general opinion expressed in the article is that 347 is superior to 321 and, in general terms, we agree with this.

With regard to oxidation, we note that 321 is considered to be twice as resistant at 1850° F. as 347. Tests which we have carried out at 1470° F. (the maximum temperature for which we would recommend either steel) indicated very little difference in the oxidation resistance of the two materials. As a matter of fact, there was a tendency for the columbium-bearing steel to be slightly better than the titanium-bearing material, but the degree of superiority was not really of significance.

The comments under the heading "Service Behavior" can be confirmed because all the types of components enumerated, as well as plant for many other applications, have been produced from the titanium-stabilized steels for many years in this country with satisfactory results.

C. Sykes
Director of Research
Brown-Firth Research Laboratories

Atomic Energy Applications

Schenectady, N. Y.

In considering the relative merits of two materials such as Types 321 and 347 stainless steels, attention is usually confined to the conventional mechanical, physical and chemical properties. For many applications in the atomic energy field, however, there is at least one additional factor to be considered — the scattering and absorption of neutrons by the material.

These properties vary widely among the metals, and small amounts of an undesirable element in an alloy are deleterious enough so that a most detailed chemical analysis of the alloy is customary for their detection. For instance, the thermal neutron absorptions of the basic ingredients and the three stabilizing elements in stainless steel have the following relation (General Electric Chart of the Nuclides, 1950):

Iron	2.4
Chromium	2.9
Nickel	4.5
Titanium	5.8
Columbium	1.2
Tantalum	21

The higher the value given above, the less suitable is the element for some applications in a nuclear reactor. Thus, depending on the particular reactor for which stabilized stainless steel is being considered, design factors may limit the kind and amount of stabilizing elements that are permissible.

L. L. Wyman
General Electric Co.

Pressure Vessels

Jersey City, N. J.

Our company was among the first users of the stabilized type of austenitic steels some 20 years ago when both the columbium and titanium types were being made available to industry. At that time the mills were having difficulty in controlling the titanium content in the 321 steel; also, some heats contained excessive quantities of nonmetallic inclusions. These problems have long since been solved, but at the time users and fabricators of heavy sections began to standardize on the columbium-bearing type, with the result that Type 347 material has been commonly specified for pressure vessels, heavy fittings and in assemblies made of massive sections. As a result we find ourselves with comparatively limited experience with Type 321 steel. Data such as those presented by Mr. Tyrrell are therefore of interest to all fabricators of stainless steel, because the shortage of columbium can be expected to result in a wider use of titanium-stabilized steel.

H. S. Blumberg
The M. W. Kellogg Co.

Welding

Milwaukee

Our use of Type 321 stainless steel has been limited to laboratory studies but we have had extensive experience with Type 347. As pointed out by Mr. Tyrrell, there are differences in the welding of various heats of Type 347, and this is true of heavy plate as well as thin sheet. The presence of columbium carbide increases the hot shortness of the material and it is often necessary to preheat plates for welding in order to avoid cracking. Such preheating is usually done between 150 and 300° F.

In our experience the use of columbium in stainless steels such as Type 347 has not resulted in satisfactory weldments from the standpoint of *corrosion resistance* at the weld-to-stock junction after stress relieving at 1100 to 1250° F. This is caused by columbium going into solution in the parent metal heated to high temperature during welding, with the result that chromium carbides form in the sensitizing temperature range unless a stabilizing heat treatment at higher temperature (1550 to 1650° F.) is

given the weldment prior to exposure in the sensitizing range. The vendors of stainless steel are aware of this deficiency, which is characteristic in either Type 321 or 347, but as yet have no solution to prevent it for all heats produced.

We have had enough experience now with welding extra-low-carbon Type 316 stainless steel to conclude that it offers considerable advantage over the columbium-stabilized grades. As yet, experimental work on weld metal characteristics is insufficient to support final recommendations about electrode compositions. However, from the standpoint of corrosion characteristics, it seems that extra-low-carbon metallic electrodes could be recommended if the final product is to be heat treated at 1600° F. or higher and air cooled. If the weldment is to be stress relieved between 1000 and 1200° F., it would be necessary to use columbium-stabilized weld deposits.

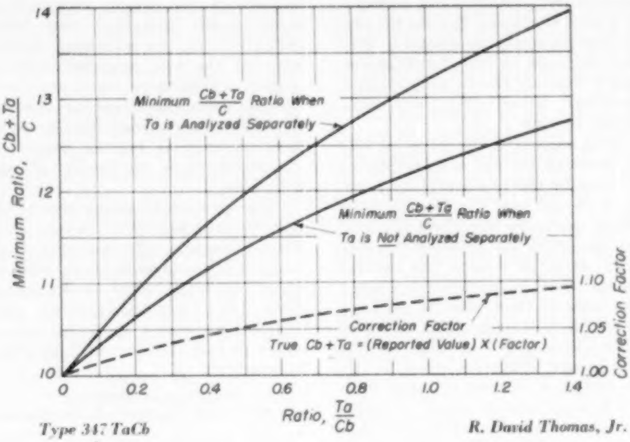
We believe that a commercial extra-low-carbon grade of 18-8 would not sensitize in the manner described for Type 347; laboratory corrosion tests have demonstrated a freedom from "knife-line" attack. However, we are not certain that the extra-low-carbon grade would be satisfactory for exhaust manifolds, as it is generally not recommended for extended service above 800° F.

M. A. Scheil
Director of Metallurgical Research
A. O. Smith Corp.

Type 347 Welding Electrodes

Philadelphia

Mr. Tyrrell calls attention to the difficulty in employing Type 321 filler rods should the columbium shortage become critical, and properly infers that columbium-bearing weld metal should be employed for welding both 347 and 321 steels.



Type 347 TaCb — *R. David Thomas, Jr.*

The welding electrode industry is well aware of the need to conserve columbium and has been taking the necessary steps to insure the availability of Type 347 welding electrodes. The almost universal practice of the industry is to produce Type 347 coated welding electrodes by incorporating ferrocolumbium in the coating on a Type 308 wire (20% Cr, 10% Ni). The dwindling supplies of ferrocolumbium have necessitated an investigation to establish the feasibility of substituting the more readily available ferrotantalum-columbium alloy. Preliminary test results on the mechanical properties of welds have demonstrated that the substitution can be made without any sacrifice in the quality of the metal. Typical tensile values recently obtained are tabulated at the bottom of this page.

Standard accelerated corrosion tests are presently being conducted on these and other compositions of weld metal to ascertain the quality of the weld metal for corrosive service. An extensive program investigating the elevated-temperature properties of the weld metal is also being prepared.

The recovery of tantalum in the weld metal has been found to be subject to the same variables as that of columbium, and to be about 70% of the value of columbium. Thus, with a given set of conditions, if columbium recovery is 65%, tantalum recovery will be about 45%.

It is well recognized that tantalum, because of its higher atomic weight, is only about half as effective as columbium in stabilizing carbon. Experience has dictated the desirability of a minimum ratio of columbium to carbon of 10; when a columbium-tantalum alloy is used, the equivalent ratio of columbium plus tantalum (analyzed together) to carbon is computed to be 11.4 for weld metal containing half as much tantalum as columbium. This equivalent ratio may be computed for any known ratio of tantalum to columbium which may be present. The accompanying curves may be useful not only to establish these minimum ratios but also to indicate the error that will be involved when columbium and tantalum are analyzed together, rather than undertaking the difficult and lengthy chemical separation.

R. David Thomas, Jr.
Vice-President and Director
of Research and Engineering
Arcos Corp.

Chemical Composition and Tensile Properties of Weld Metal*

Test No.	C	Mn	Si	Cr	Ni	Cb + Ta†	Heat Treatment	Yield Strength	Tensile Strength	Elong. in 2 In.	R.A.
6804	0.068	1.61	0.55	19.96	10.25	1.05	As welded	75,000 psi.	97,000 psi.	33%	46.5%
		Standard Ferrocolumbium					4 hr. at 1300° F.	75,000	103,500	25.5	37.5
							4 hr. at 1550° F.	66,500	95,500	30.5	48
6807	0.065	1.98	0.61	19.83	10.11	1.15	As welded	74,000	97,000	32	51
		Ferrotantalum-columbium					4 hr. at 1300° F.	76,500	105,000	25	37.5
							4 hr. at 1550° F.	66,500	96,000	30	48

*All-weld-metal tensile specimens were 0.505-in. diameter. †Reported as Cb by conventional analytical methods.

Tantalum-Columbium

PITTSBURGH

The new tantalum-columbium stainless steel is made with ferro-tantalum-columbium alloy which contains about 40% columbium, 20% tantalum and 0.25% carbon, the remainder being chiefly iron. This ferro-alloy has been added to 18-8 in amounts that give a steel of nominal composition 18% chromium, 10% nickel, 0.6% columbium and 0.25% tantalum, with 0.06% carbon. Steels of this type have been tested at room temperature, 1000, 1200, 1350 and 1500° F. and as far as we are able to determine, their strength and ductility are comparable to those of Type 347 steel made with the regular ferrocolumbium alloy. The hot workability of the 18-8 steels containing columbium and tantalum is also comparable to that of the regular 347 steel.

In intergranular corrosion tests using acidified copper sulphate solutions, nitric acid solutions, and nitric-hydrofluoric solutions the resistance of the 18-8 steel containing columbium and tantalum to intergranular corrosion is equal to that of the regular 347. In fact, the 18-8CbTa steel having a columbium + tantalum content of at least ten times the carbon content has met all the corrosion requirements generally specified for 347, which shows that this steel is a good substitute for the regular Type 347.

RUSSELL FRANKS
Manager—Development
Electro Metallurgical Division
Union Carbide and Carbon Corp.

More on British Aircraft*

BRISTOL, ENGLAND

The British specifications covering weldable stainless steel sheets have hitherto quoted titanium and columbium only as optional elements, the main requirement of the specifications being that the material should withstand the weld decay test. It would be possible, therefore, for the supplier to furnish steel without either of the two elements, provided the carbon content was sufficiently low to avoid weld decay troubles. In actual fact the bulk of material supplied has contained titanium and in general this has given satisfactory results. A recent revision of these specifications has been made and now titanium or columbium in the appropriate amounts (depending on carbon content) is specified as an essential element.

E. R. GADD
Engine Division
Bristol Aeroplane Co., Ltd.

LONDON, ENGLAND

Mr. Tyrrell presents a good case for the diversion of columbium as a stabilizer for stainless steel to higher-priority demands as, for instance, its use in disk and blade alloys for gas turbine engines. Since the rating of critical alloying elements places columbium as the most scarce material, and with the present availability of titanium as it is, there is every reason for making a fuller use of titanium as a stabilizer for stainless steels.

At Napier's, where 18-8 stainless steel pressings are fabricated by torch welding methods, we have always accepted the titanium-inoculated composition as our standard quality. Over a long period our metallurgical laboratory has had no major problems to deal with concerning weld decay on components such as, for instance, exhaust stubs for one of our engine types. It is interesting to note that three grades of filler wire or rod have been employed for the welding of these exhaust stubs, one containing no stabilizer, one with a titanium addition and one with columbium. Any preference for a particular filler would appear to be a personal opinion on the part of the operator.

Where assemblies specified in 18-8 steel are fabricated by spot or stitch welding methods, again we use only the titanium-stabilized material. So far, no problems have been encountered in weldability.

Metal-arc welding is not applicable to the majority of our components where welding is called for. Where heavy-section stainless castings are welded by the metal-arc process we have a preference for columbium-bearing welding rods.

J. K. WILSON
Chief Metallurgist
D. Napier & Son, Ltd.

DERBY, ENGLAND

Utilization of columbium-stabilized stainless steels at Rolls-Royce, Ltd., has been negligible, but titanium-stabilized steels have been in production for more than 20 years. Exhaust systems on automobiles, exhaust stubs and manifolds on aero piston engines, jet pipes, and exhaust cones and nozzles on jet engines have given satisfactory service up to 1400° F.

The titanium steels have been welded by all production methods —torch, arc (open and shielded) and electric resistance. Titanium steel sheet, 0.048 in. thick, is seam welded at 30 in. per min. to give a gas-tight joint. For torch welding, the titanium content must not be too high, to avoid sluggishness, nor too low to give an unstabilized weld deposit due to titanium depletion. For torch welding we confirm the author's finding that columbium electrodes are more consistent.

In general, U. S. steel manufacturers are able to supply stainless steels of lower carbon content than British firms, and the need for stabilization decreases with the lower carbon content. But even with carbon as low as 0.04% it has been our experience that stabilization is necessary for all welded parts or parts subject to service temperatures in excess of 1300° F.

H. E. GRESHAM
Chief Metallurgist
Rolls-Royce, Ltd.

BURNLEY, ENGLAND

Our experience covers the manufacture of exhaust units and jet pipes for gas turbine engines from sheet metal in gages varying from 0.032 to 0.064 in., for operation at temperatures from 1100 to 1300° F. In these units, we have used many tons of titanium-stabilized 18-8 sheet with complete satisfaction.

H. E. LARGE
Joseph Lucas, Ltd.

WEYBRIDGE, ENGLAND

Stainless steels of the 18-8 type have been used by my company for exhaust manifolds for the past five or six years. During this period a number of failures have occurred and these can be attributed to the following causes: Inadequately stabilized material, faulty design, and faulty processing of the fabricated parts. Titanium is being used more generally than columbium and would appear to be quite satisfactory, providing the content does not fall below the recommended minimum of five times the carbon content. We have no reason to suspect that 18-8 steel fully stabilized with titanium is unsatisfactory for ex-

*See also discussion on p. 766, received too late for inclusion here.

haust manifolds when used at temperatures of the order of 1200° F.

Failures of manifolds have often been attributed solely to the use of unsuitable material, but in fact the contributory causes have been faulty design and inadequate processing of the fabricated parts. The gage of material is often too thin and insufficient provision is made for the free displacement of the unit when submitted to thermal stresses.

The omission of annealing before and after welding has led to cracking of the manifolds, while the lack of adequate surface preparation has resulted in faulty welds.

J. H. Cork
Aircraft Section
Vickers-Armstrong, Ltd.

Belfast, Ireland

In stabilized chromium-nickel heat resisting steels of the 23-18 and 23-14 types made to British Standard Specifications S108 and S109, the titanium and columbium contents are respectively 4 and 8 times the carbon content of 0.2% max. However, better proportions would be 5 and 10 times carbon, to ensure sufficient stabilizing effect when the carbon is at its top limit.

R. E. Packer
Seaplane Works
Short Bros. & Harland, Ltd.

Coventry, England

To most English readers, Mr. Tyrrell's informative article will be of interest in that it justifies a practice long established in this country — the use of titanium in preference to columbium as the stabilizing element in austenitic stainless steel, particularly in the aircraft industry. To have insisted on columbium-stabilized sheet during the war would have caused grave difficulties in supply; nor was there ever any convincing evidence that subsequent manufacture would have benefited or reliability increased, at least so far as aircraft were concerned.

Chemical analyses covering a very large number of production supplies delivered to our works over many years show that almost all of the austenitic steel sheet purchased in conformance with the weld decay test has been stabilized with titanium. It would be futile to pretend that we had no trouble with any of this sheet but I cannot recall a single instance of trouble in service or production in which there was any evidence that changing over to columbium-stabilized sheet would have got us out of our difficulty.

In service most of the failures were caused by fatigue or by various troubles associated with overheating (primarily excessive oxidation and attack from exhaust gases and corrosive deposits). Creep failures and failures resulting from alternating thermal stresses have arisen less frequently. Most troubles were overcome by design alterations such as the elimination of vibration, improvements in the fatigue strength of the structure, and greater cooling. Change of material was made only on rare occasions and when definite evidence for its desirability was forthcoming and in such cases the changes were to materials of basically different composition.

Columbium-stabilized sheet is made over here, of course, but usually for special purposes. For example, one of the largest steel firms supplies it in view of their claim that it gives somewhat better creep properties over a certain temperature range.

All this is in agreement with the observations and laboratory tests mentioned by Mr. Tyrrell. I would add that we have carried out cracking tests on sheet test pieces under conditions of alternating thermal stresses and that these show no advantage for the columbium-stabilized material. High-temperature fatigue tests have indicated no apparent difference and creep-to-rupture tests on welded test pieces have shown that variations in the welding technique, rod and flux composition completely mask the effect of differences in the base metal composition of the type under discussion.

These remarks apply to wrought material. The position is not quite the same when we come to the question of castings. Centrifugally cast rings for turbine shrouds, for instance, are, if made of 18-10 material, usually stabilized with columbium. This is entirely a matter of preference on the part of the foundries, which report greater difficulty in the production of metallurgically clean castings and control of composition when using titanium. Nevertheless, titanium-stabilized castings are being made and one of the foremost manufacturers in this country has pointed out that while in general he much prefers to use columbium, the use of titanium may be of advantage because less trouble is encountered from hot cracking. This point may be related with that made by Mr. Tyrrell concerning the hot cracking of welds.

My impression is that in Britain we are very much more titanium conscious in a number of respects. Mr. Tyrrell mentions the large amount of columbium being used in gas turbine parts in America. This is not so in Britain. Almost all our jets and prop-jet engines are fitted with Nimonic 80 or 90 blades which are hardened with titanium. Austenitic turbine disks containing columbium have been widely used over here but alternative austenitic steels free from columbium are now available and there is a general tendency to go over to ferritic steels containing no columbium, or in amounts very much less than are added to the austenitic steel mentioned above. Some firms have in fact been using columbium-free ferritic steels for turbine disks all along. It would hardly be an overstatement to suggest that, with the exception of certain welding rods, columbium could be eliminated completely from our highest-powered jet engines with no marked effect on the manufacture or performance.

S. T. Harrison
Chief Metallurgist
Armstrong Siddeley Motors, Ltd.

Back to the States

Chula Vista, Calif.

Type 347 steel has been increasingly preferred for years despite its higher cost, as compared to Type 321, when a stabilized variety of 18-8 was required.* Examination of many heats of Type 321 at Rohr Aircraft Corp., over a period of years, has demonstrated the inability of titanium to provide proper and consistent stabilization after exposure to sensitizing temperatures.

*Editor's Note: The extent of this preference during recent years may be judged by the following figures for production of stainless steel ingots of the two types. Data were reported by the American Iron and Steel Institute. Note high production of Type 321 during wartime and the change back to 347 in 1946.

	Type 347	Type 321
1942	29,755 tons	53,525 tons
1943	33,064	60,145
1944	26,988	61,641
1945	32,364	37,338
1946	16,113	3,555
1947	22,966	6,949
1948	33,346	7,528
1949	26,710	5,575
1950 (a)	17,470 (a)	3,616 (a)

(a) For first six months only.

Using Type 347, we have been able to produce high-quality stabilized welds more consistently and at greater speeds than was possible with 321. Type 321 rods are not used because of the "burning" of titanium. The welding of "standing edge" joints, which do not require rods, is not recommended for the same reason.

The successful forming of many intricately shaped parts at Rohr from 347 rather than 321 can be explained, in part, by the fact that the columbium variety is generally "cleaner" metallurgically, as observed during many microscopic examinations.

BERNARD GROSS
Director of Laboratories
Rohr Aircraft Co.

As Melted in 1947 As Melted in 1950

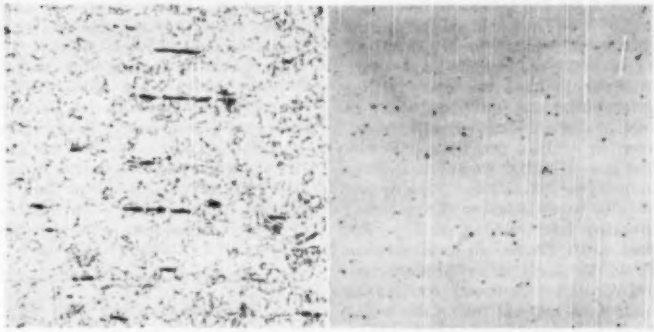


Fig. 1 — Inclusion Content of Type 321 Seamless Tube. (Left) Electrolytic oxalic acid etch; 125×. (Right) Unetched; 100×

Drawn Tubing

NORRISTOWN, PA.

It is no secret that the stabilized varieties of stainless steel have frequently shown poor performance in exacting mechanical applications because of an unusually high content of nonmetallic inclusions. Much progress has been made during recent years in cleaning up the titanium-stabilized 321, as indicated by the typical micrographs in Fig. 1. The columbium-stabilized 347 has not suffered so much from this defect, but the average inclusion rating of 347 has, nevertheless, been a matter of concern in some uses.

Precision tubing has recently been drawn from both seamless and "Weldrawn" stock in the new tantalum-columbium variety of 347. Because of the greater amount of stabilizing elements present in this steel it might be expected that the inclusion rating would suffer. However, the inclusions in 347TaCb, though of slightly different form, seem to be present in no greater quantity than in the 347Cb (Fig. 2).

In workability and weldability we find little to choose between the regular 347 and its tantalum-bearing congener. The simple Strauss test has been met as satisfactorily with tantalum-bearing 347 as with the regular type, at least where the columbium-to-tantalum ratio is approximately 4 to 1. Cooperative efforts among many laboratories will be required before one can know the differences and similarities between 347Cb and 347TaCb in specific corrosion resistance and high-temperature strength.

Our own experience so far is limited to three heats melted by different producers, and that experience has been wholly satisfactory.

D. H. WIESE and H. W. COOPER
Metallurgical Department
Superior Tube Co.

Hot Workability

MILWAUKEE

Mr. Tyrrell mentions the red shortness of Type 347 steel in his discussion of the cracking of welds but does not refer to this difficulty in other hot fabricating operations. We have investigated both of the stabilized grades of stainless steel by means of the hot twist test developed in the laboratories of Globe Steel Tubes Co., and results have been published in *The Iron Age* (April 20, 1944) and the *A.I.M.E.*

Seamless Tube Stabilized With Cb | Seamless Tube Stabilized With Ta and Cb | Cold Rolled Strip Stabilized With Ta and Cb

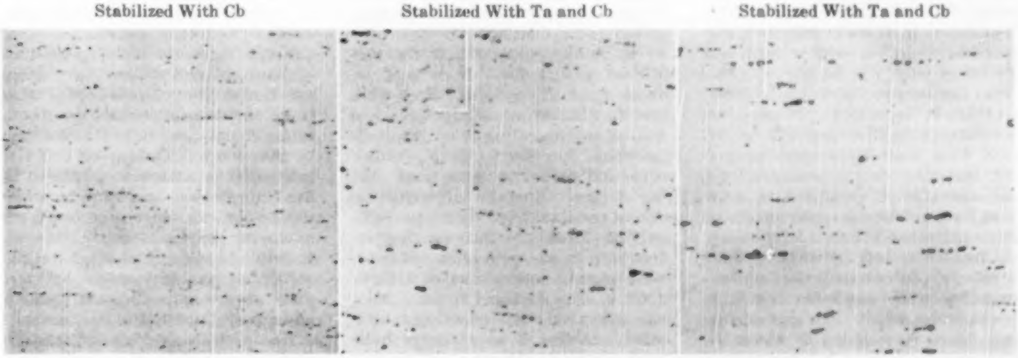


Fig. 2 — Inclusion Content of Type 347 Stainless Steel. 100×. (Left) Unetched. (Center) Longitudinal section; electrolytic oxalic acid etch. (Right) Longitudinal section; unetched

Transactions (Vol. 167, 1946, p. 749 to 790). In the latter publication, a graph was included showing the spread of results for ten heats of Type 321. Those data and other evidence indicate the necessity for determining the hot workability of each heat of steel individually. However, as a class, the Type 321 steel has much better hot workability than Type 347. Thus, there would be less scrap loss in the piercing or other hot working of Type 321 than with similar operations on Type 347. Such scrap cannot be remelted under ordinary oxidizing conditions without losing the major portion of the scarce columbium.

HARRY K. IHRIG
Vice-President
Globe Steel Tubes Co.

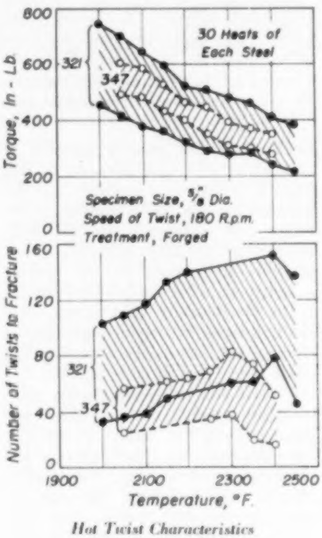
Again — When Is a Stabilized Steel Necessary?

CANTON, OHIO

Mr. Tyrrell has presented much pertinent information as the basis for his conclusion that Type 321 is a suitable replacement for Type 347. However, his statements with respect to the high-temperature properties of these steels might well be expanded.

Thus, Table III of his paper gives the reported stress ranges for 0.0001% creep per hr. at a series of temperatures and also shows an average value. It is questionable whether this average has any meaning. We have found that apparent grain size has a pronounced influence on all the high-temperature properties of these *stabilized* grades and consequently the grain size should be reported with any high-temperature data (*A.S.M. Transactions*, Vol. 38, 1947, p. 148 to 179). For example, there is greater difference between 347 with a grain size of 8 and with a grain size of 2 to 4 than between many radically different steels or alloys. It does not necessarily follow that 321 or 347 will have high-temperature properties superior to the standard 18-8, because similar variations in grain size have relatively slight effects on the unstabilized steel.

Insofar as ease of working these steels is concerned, the author's remarks were confined largely to room temperature. The accompanying figure is included to show the differences in their hot twist characteristics over the temperature range used for hot processing, such as forging and piercing into seamless tubes. Thirty heats of each grade were considered and, as would be expected for steels of this type, there is considerable spread in both the number-of-twist and torque values, even though each of the heats was properly balanced to prevent the formation of free ferrite at the hot working temperatures. However, the figure shows that, in general, 321 has the greater number of twists to fracture and also has



Hot Twist Characteristics

the higher temperature of maximum twist (2300°F. for 347 and 2400° F. for 321). From this it follows that 321 can be hot worked somewhat more readily than 347 and, at least in our own operations, this has been found to be true.

It is our opinion that the stabilized grades have been used in many applications where they were not needed. Many metallurgists feel that if the operating temperature is between 800 and 1500° F., either Type 321 or 347 must be used. Yet the largest tonnage of austenitic steels used in high-temperature service — until recently at least — has been in the petroleum industry, with metal temperatures of 1100 to 1500° F. The standard 18-8 has been the most widely used austenitic steel, and few if any failures have been encountered while the tubes were hot, even though the conditions were very corrosive and pronounced structural changes occurred, accompanied by intergranular carbide precipitation. We have examined 18-8 tubes after 100,000 hr. of service and found no indications of excessive intergranular oxidation or corrosion (*A.S.M. Transactions*, Vol. 35, 1945, p. 298-330). It is true that if a corrosive condensate is permitted to form, intergranular attack may occur at room temperature or slightly above, but there are often procedures that may be followed to prevent the formation of this condensate.

Wherever possible the standard 18-8 analysis should be used, for this is still the most foolproof of all the austenitic grades. Its hot workability is certainly superior to the stabilized grades, its mechanical properties at elevated temperatures are independent of many variables that influence the stabilized grades, and it is generally much freer from surface or subsurface imperfections.

C. L. CLARK
Metallurgical Engineer
Timken Roller Bearing Co.

Once More — When Is a Stabilized Steel Necessary?

PITTSBURGH

We believe that discussion of columbium conservation is timely and useful, particularly if it leads to ways and means that will effect reductions in the use of this critical element. Rather than to discuss Mr. Tyrrell's article, in which he very ably outlines his experience in the use of both columbium and titanium-bearing compositions, we propose that consideration be given to the possibility of conserving columbium by other means.

During the course of our association with the requirements of stainless steels for high-temperature systems in aircraft, we have often questioned the requirement that these stabilized materials must contain sufficient amounts of columbium or titanium to enable them to resist intergranular attack as evaluated in the laboratory by exposure to selective boiling corrosive solutions, such as copper sulphate – sulphuric acid. In other words, we ask: Is the ability of stainless steels to meet these severe embrittlement tests in any way related to the performance of these steels in high-temperature service? Is it not probable that smaller amounts of these additions would provide steels that are equally

satisfactory? Indeed, is it not possible that just plain old-fashioned 18-8 would give as good account of itself as its stabilized modifications?

The basis for our reasoning may be summarized as follows:

1. We have observed that most of the failures of exhaust systems returned to our laboratories for investigation have been of a fatigue type which in our opinion was not associated with the ability of the material to meet the embrittlement test.

2. Mr. W. G. Hubbell in another very pertinent article, "Effect of Stabilizing and Stress Relief Heat Treatment of 18-8 Stainless" (*Steel*, August 25, 1947), reports his findings on stabilized material from exhaust systems which had been in service for as long as 4000 flying hours. His investigation shows no correlation between the service life of such materials and their ability to meet the embrittlement test.

3. Such compositions as 25-20 and 25-12 containing carbides in the grain boundaries (to the extent that the steels are susceptible to intergranular corrosion by selective wet corrosive reagents) have been used in high-temperature systems of aircraft and have performed well.

4. Exhaust systems of military aircraft (even fighter planes exposed to corrosive salt atmospheres) were shrouded with Type 302 steel during the last war. We have observed heat tint and oxidation on such shrouding to a degree that suggests that the shrouding was subject to operation in the carbide precipitation range. Apparently such material was satisfactory and did not fail by intergranular corrosion.

5. Intergranular attack may result from causes other than chromium carbide precipitation. For example, we have observed intergranular attack induced by the deposition of the lead compounds which result from the combustion of leaded fuels. The use of columbium or titanium does not inhibit such attack.

The foregoing comments are offered with the recommendation that, in the interest of conservation, investigations should be undertaken to establish the relative merits of materials under actual conditions of service. These investigations, we believe, should include the unstabilized as well as the stabilized grades of 18-8 stainless steels, with varying amounts of columbium or titanium.

We are not aware of any systematic investigation that supports any correlation of corrosion tests with service performance. We suggest, therefore, that unless such studies have been made or until they are made, under conditions closely associated with those of flight and field service, we may be perpetuating the use of critical materials where they are not needed.

D. C. Buck
Metallurgical Engineer
Carnegie-Illinois Steel Corp.

Intergranular Cracking in Aircraft Parts

Washington, D. C.

I concur heartily with Mr. Tyrrell in emphasizing the importance of conserving columbium *now*, wherever possible. His thesis — the rather general substitution of titanium-stabilized stainless steel for the columbium-stabilized type — is unlikely to be accepted unanimously, for this subject is one of perennial debate. Numerous denials notwithstanding, there seems to be a definite prejudice against such a substitution, often for reasons rather dubious and ambiguous. There is a legitimate question, however, as to whether the two steels are always interchangeable with respect to serviceability, and each significant type of application should be judged on its own merit.

One point regarding interchangeability is often misunderstood and warrants clarification. I refer to the question of government specifications. In spite of the above question as to complete interchangeability, the Air Force - Navy specifications for aircraft and related items include both compositions of steel in all stabilized stainless steel specifications, and both types are acceptable on an equal basis. Stated somewhat differently, the prime contractor is given complete freedom to use either type for a given application. The Bureau of Aeronautics has, in fact, urged its contractors to select the Type 321, unless the contractor considers this type unsuitable in a specific application. The generally satisfactory service performance of stabilized stainless steel resulting from the above policy on interchangeability speaks for itself. In a similar manner, the Bureau of Aeronautics has indicated its willingness to accept columbium-tantalum combinations, in accordance with applicable specifications, as a completely interchangeable alternate, except in stainless welding rod, where, pending compilation of necessary data, columbium is still required. It may be anticipated, however, that columbium-tantalum combinations (at least up to about one-third tantalum) will eventually prove to be acceptable in welding rod also.

Mr. Tyrrell has very ably and convincingly discussed several factors relating to selection of a stabilized type: Welding characteristics, forming, casting, and several engineering properties, particularly creep and short-time tensile strength. Other factors that must be considered in many designs are: Resistance to intergranular corrosion and embrittlement, long-time rupture and fatigue resistance at various temperatures, ductility (beyond elongation), surface condition, freedom of final product from inclusions and segregates, and cost. I would like to take this occasion to discuss intergranular attack, omitting the other factors in the interest of brevity.

Extensive work has been done on steels "sensitized" from about 900° F. upward, to determine their resistance to copper sulphate solutions as a measure of resistance to intergranular corrosion and embrittlement. Let us defer for a moment the question of significance of these tests. An excellent summary of recent data is given by S. J. Rosenberg and J. H. Darr in *A.S.M. Transactions*, Vol. 41, 1949, p. 1261. From these data it is evident that resistance to the copper sulphate test is generally inferior in Type 321 steel unless adequate precautions are taken to have a high ratio of titanium to carbon (upward of 6:1), or unless a "thermal" stabilization at approximately 1600° F. for about ½ to 1 hr. is given. Previous thermal and mechanical history is important. It is worth repeating, however, that where the Ti/C ratio is high enough, results comparable to Type 347 are obtained.

The question that logically follows is, briefly: "So what?" The same question has been asked, incidentally, concerning the significance of endurance limit of carefully polished specimens, the transition temperature of steels, notch-impact strength, tensile elongation in a 2-in. specimen, and a host of other properties, but it may be that any similarity between these questions is purely coincidental. Certainly the

hazard in extrapolating from empirical laboratory tests — particularly corrosion tests — to service operation is well recognized and cannot be overemphasized. Nevertheless, other things being equal, poor results in any of the above properties may be a danger signal that should not be disregarded without careful consideration. Conversely, if it is practical to avoid these danger signals where they might be applicable, regardless of their real significance, the user may have more confidence in his product, a bigger "factor of safety", so to speak.

The desirability of such a safety factor, when feasible, has often been illustrated. For example, in one service experience, Type 316 steel was used in a high-temperature supercharger application, and normally operated satisfactorily, but just on the margin of what is usually considered the sensitizing temperature range. Due to a change in related equipment (heat exchanger) and operation, the operating temperature of the component in question dropped to approximately 1300° F., with subsequent intergranular attack, embrittlement and failure of the steel. An original, relatively inexpensive, extra precaution of using a well-stabilized steel, possibly with molybdenum added, would have paid dividends in avoiding any necessity for expensive, time-consuming material changes.

Another favorite question relating to intergranular corrosion is: "What is the minimum ratio of titanium to carbon necessary for practical immunization?" Normally, a ratio between 5 and 7 seems to be preferred. The following service experience may be of interest, although I have deliberately avoided any positive conclusion with respect to the interrelation between titanium-carbon ratio, intergranular attack and service correlation with laboratory results, due to several possible explanations of varying probability.

This example refers to airplane exhaust manifolds which had cracked and then partially broken off in service. Analysis showed some of the steel involved to be Type 321 with carbon approximately 0.09% and titanium/carbon ratio approximately 8. Thus a high degree of immunity to intergranular corrosion would have been expected, at least on the basis of accelerated laboratory tests.

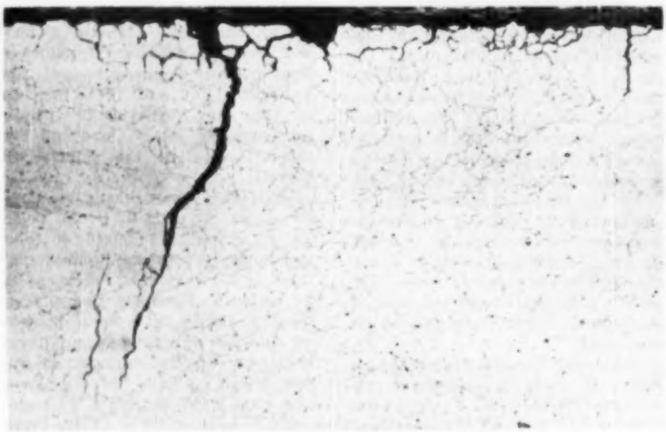


Fig. 1 — Cracks in Exhaust Manifold (Type 321 Steel) Apparently Originating at Areas of Intergranular Attack on Inside Surface. Note region of abnormal grain size. Etched electrolytically in chromic acid; 100 ×

The major cracks appeared to be the result of stress corrosion but study of the inside surface exposed to exhaust gases showed the origin of the cracks to be intergranular (Fig. 1), becoming transgranular as they progressed. Thus intergranular attack appeared to be the original cause which led to the ultimate failure, by serving to concentrate the stresses. Although a titanium/carbon ratio of 5 (or even 4) has often been stated as satisfactory based on extensive experience, these values were primarily the minimums in the applicable specifications, whereas the values in the material actually used have generally been higher. Note, for example, that Mr. Tyrrell gives results of statistical analysis of 77 heats indicating an average titanium/carbon ratio *greater than 9*.

It would appear, in recapitulation of the above, that the substitution of titanium-stabilized steel for the columbium type is generally either permissible or warrants serious consideration. Nevertheless, from the point of view of serviceability, the specific requirements of the application must be carefully evaluated or a preliminary service test must be conducted before final decision is made. Where deteriorating influences exist, adequate stabilization must be insured, either through the medium of adequate titanium/carbon ratios or thermal stabilization; otherwise, the conservation of a small amount of stabilizing element may require payment in terms of replacement of an entire component, involving considerable critical alloy, man-hours, disability of equipment, money and perhaps more disastrous results. Thus, it is extremely difficult, to say the least, to present *a priori* any extensive list of applications where steels properly stabilized with titanium and properly processed would be unsatisfactory, except possibly to stress the need for caution in high-temperature applications involving gas welding, continuing high or vibratory stresses or highly deteriorating environments.

Another question that has often been raised is whether stabilized grades are necessary at all for high-temperature operation. The preceding paragraphs in this discussion, and additional data, definitely preclude any categorical statement that stabilized steels are unnecessary. It is true that in certain applications involving moderate time, temperature and exposure conditions, low-carbon (0.03% max.) stainless may be entirely suitable. As previously stated, the specific type of application must first be studied or service-type tests conducted. It is as unjustified to arbitrarily apply conclusions from one set of operating conditions (perhaps only partially definable) to another type of

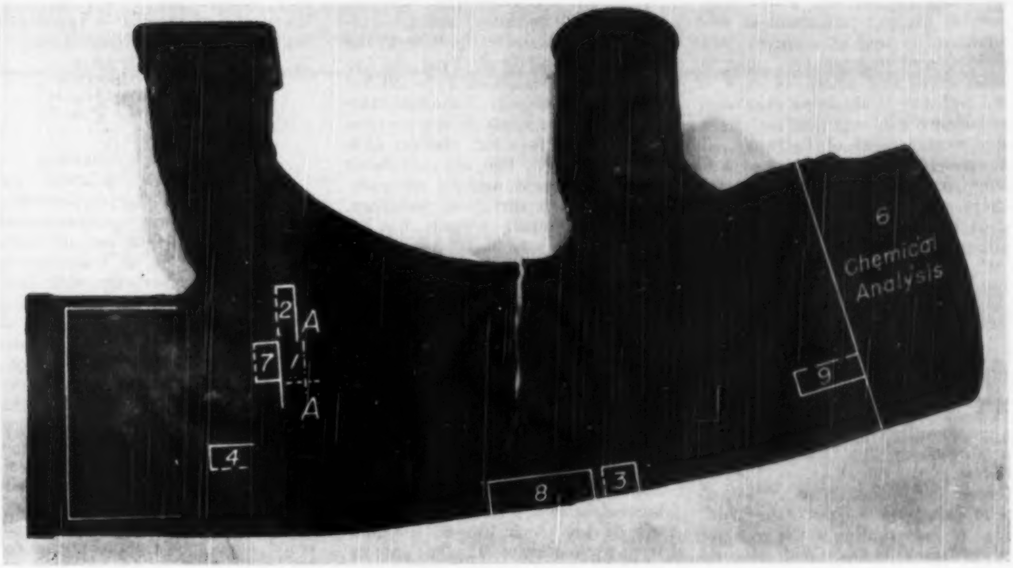


Fig. 2 — Appearance of Failed Exhaust Collector Ring As Received for Investigation. Failure occurred in portion made of unstabilized stainless steel. Numbered areas indicate sections taken for test. Dotted lines indicate planes on which micro-examinations were made. Component is shown at about 2/5 actual size

application as it is to extrapolate from accelerated laboratory tests, but too often this is done.

Again by way of example, it appears that the petroleum industry utilizes unstabilized stainless successfully at high temperatures. Yet, a number of aircraft exhaust components made in part from unstabilized steel and in part from stabilized steel, have failed in service completely in the unstabilized portions. Figure 2 illustrates how the unstabilized material cracked and broke away. Figure 3 shows the severe intergranular corrosion found on the inside surface of the unstabilized steel only. Nevertheless, the low-carbon unstabilized stainless may be substituted in a number of less critical applications, and in any case, the melting of lower-carbon *stabilized* stainless permits conservation of columbium per se, as well as, alternatively, the use of high titanium/carbon ratios while still retaining low titanium content, with possible advantages in improved cleanliness and ductility.

It would seem feasible, also, to produce at least a substantial percentage, if not all, of the required amount of low-carbon stainless in an emergency, in spite of potential shortages of low-carbon ferrochromium, particularly when it is recalled that in one current large-scale process of producing stainless, utilization of direct reduction of chrome ore obviates the need for low-carbon ferrochromium.

In conclusion, the substitution of Type 321 for 347 offers greater promise than any other single measure for conserving columbium. Additional columbium can be conserved by lowering the carbon *in the stabilized grades,* by using the unstabilized 0.03% carbon maximum type in some components, by using columbium-tantalum stabilizing combinations, and even by using columbium-titanium stabilizing combinations, for which favorable data exist. It appears highly significant also, based on Mr. Tyrrell's data, that 85% excess columbium is used over what is actually called for.

Important end-uses must be studied carefully, however, and the selection of material must be based on the requirements of the individual uses. Sometimes only service tests will give the positive answer.

The above discussion has been slanted toward the more critical ap-

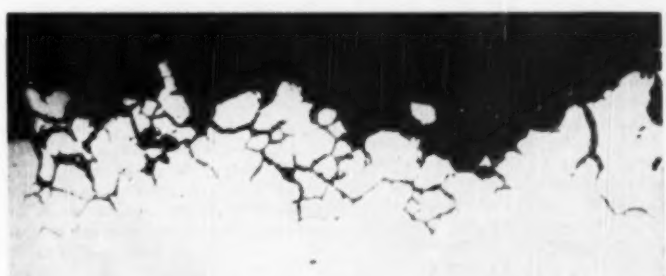


Fig. 3 — Severe Intergranular Corrosion at Inside Surface of Unstabilized Steel in Failed Collector Ring Shown in Fig. 2. Unetched; 100×

plications in aircraft, where jeopardy of life and fulfillment of vital missions, as well as economy, production and maintenance, must be considered; and where, in view of the difficulty of obtaining conclusive experience data and positive, exclusive explanations of failures, all danger signals must be viewed with concern. Obviously, there are many simpler applications of stainless steel where such detailed considerations are not necessary.

N. E. PROMISEL
Head, Materials Branch
Navy Bureau of Aeronautics

Stabilized Castings

MINEOLA, N. Y.

Very limited quantities of titanium-stabilized castings have been produced by the alloy casting industry in the United States. Conversely, production of columbium-stabilized castings of the CF-8C type (corresponding to the wrought alloy Type 347) has shown a steady increase in tonnage as well as in percentage of total output. The following tabulation of shipments shows the growth in demand for stabilized alloys in the postwar years. The increase in 1949 is especially significant because the total output of corrosion resistant castings declined in that year with respect to 1948.

	CB TYPE	TI TYPE
1946	485,000 lb.	160 lb.
1947	461,000	1650
1948	505,000	†
1949	834,000	†
1950*	710,000*	†

*First 7 mo. (est.) †None reported.

In view of the present necessity to eliminate columbium from all but the most essential uses, it is encouraging to learn from Mr. Tyrrell's article that Solar Aircraft Co. has made a successful start on overcoming previous objections relating to production of titanium-stabilized castings in the foundry. Although the stabilized cast alloys were studied in past research programs, the Technical Research Committee of the Alloy Casting Institute recently began a new project at Battelle Memorial Institute directed toward a more extensive investigation of the corrosion resistance and castability of titanium-stabilized compositions.

E. A. SCHOEFER
Executive Secretary
Alloy Casting Institute

BIRMINGHAM, ALA.

The steel and alloy casting foundries have generally preferred the columbium-stabilized Type 347 to the titanium-stabilized Type 321 for three reasons: *(a)* Titanium-stabilized stainless steels do not perform well in the Huey test (boiling 65% nitric acid), *(b)* they are considered difficult to weld without adversely affecting their corrosion resistance, and *(c)* titanium is easily lost by oxidation in the ladle or during pouring.

None of these is a conclusive reason for not using the titanium-stabilized steels. The Huey test is a test for the resistance of a metal in boiling 65% HNO_3 only, and tells nothing about its resistance in other mediums; it is known that the titanium-stabilized steels are quite resistant to many mediums. Welding with titanium-stabilized rods has not been successful but with columbium-stabilized rods there should not be too much loss of titanium from the parent metal. The loss of titanium in the ladle and during pouring can be compensated for by careful practice. Therefore, for many services, the objections are nonexistent or can be overcome, and Mr. Tyrrell's point for conservation is well taken, especially in view of the considerable advantages for the titanium steels which he has pointed out.

CHARLES K. DONOHO
Chief Metallurgist
American Cast Iron Pipe Co.

ELYRIA, OHIO

I believe the points made by Mr. Tyrrell are well taken. In my opinion, there is no reason why the titanium-stabilized material should not be a logical substitute for elevated-temperature service where creep strength and hot gas corrosion resistance are predominating significant properties.

We know from our experience and data that additions of columbium to the 18-8 and 25-12 types of alloy castings impair oxidation resistance severely. The adverse effect of titanium is much less.

Because of the common idea that titanium impairs the fluidity or foundry handling characteristics of stainless and heat resistant alloys, we have not experimented with it to any appreciable extent. It is unlikely that these troubles are severe, and our company, as well as many other producers of alloy castings, will devote considerable effort in the next few months to investigating the titanium-modified alloys.

N. A. MATTHEWS
Division Metallurgist
Electro-Alloys Division
American Brake Shoe Co.

DETROIT

As Mr. Tyrrell indicates, the present necessity for conservation of columbium requires a reappraisal and an investigation into alternate practical methods of stabilization.

Our own experience with titanium stabilization is somewhat limited; however, early attempts at the production of titanium-stabilized castings indicated a fluidity problem and, as Mr. Tyrrell has mentioned, some "fading" of titanium. The mechanical properties of cast titanium stainless have been found entirely satisfactory and tests in our laboratory check those of the author very closely.

It would appear that Mr. Tyrrell could offer a distinct contribution by elaborating on his methods of producing castings, particularly as regards the manner of introducing titanium into the melt, the recovery of titanium both from the ferro-alloy and from titanium-bearing scrap, and the fluidity and casting characteristics experienced.

R. J. WILCOX
Technical Director
Michigan Steel Casting Co.

SHEFFIELD, ENGLAND

We unfortunately have no easily available statistics at our disposal to demonstrate the relative extents to which columbium and titanium have been used now or in the past in this country, but I think we can say without doubt that, insofar as steel castings are concerned, there has been a marked preference over the last ten years or so for columbium.

It seems equally certain that this preference is the result of the better fluidity and the better mechanical test figures steel founders normally obtain from the columbium-treated steels on the one hand and of the relatively high losses of titanium during steelmaking on the other. In addition, many producers have found greater difficulty in meeting the copper sulphate – sulphuric acid test when using titanium.

It must of course be said that these alleged disadvantages of titanium have been magnified by the

(Continued on p. 742)

The perchloric-acetic electrolytic method is superior to mechanical polishing and chemical etching for zirconium and zirconium-uranium alloys.

Metallography of Zirconium

INCREASING INTEREST in zirconium for many applications beyond the small amounts used in deoxidizing steel has created a need for methods of evaluating the structure and properties of the metal and its alloys. The metallography of zirconium — like all metallography — has two related but distinct problems. One is the preparation of surfaces for microscopic examination; the second, interpretation and standardization of structures. Satisfactory progress has been achieved along both lines, particularly the first.

Zirconium resembles other rare metals closely, but certain characteristics of it render ineffective the methods ordinarily used in sample preparation. In this laboratory, mechanical polishing and chemical etching never seemed to produce optimum results. A variation of the perchloric-acetic electropolishing method has been found most useful for zirconium and many of its alloys.

The procedure outlined here is fast and fairly simple. Preparation of the sample, prior to electropolishing, consists of customary paper grinding, finishing with grit 3/0. Anything finer than 3/0 tends to smear zirconium rather than to cut it. Samples are unmounted, providing good electrical

NOTE: This work was carried out at the M.I.T. Metallurgical Project under Contract No. W-7405-eng-175 with the U. S. Atomic Energy Commission.

By H. P. Roth
Metallurgical Project
Massachusetts Institute of Technology

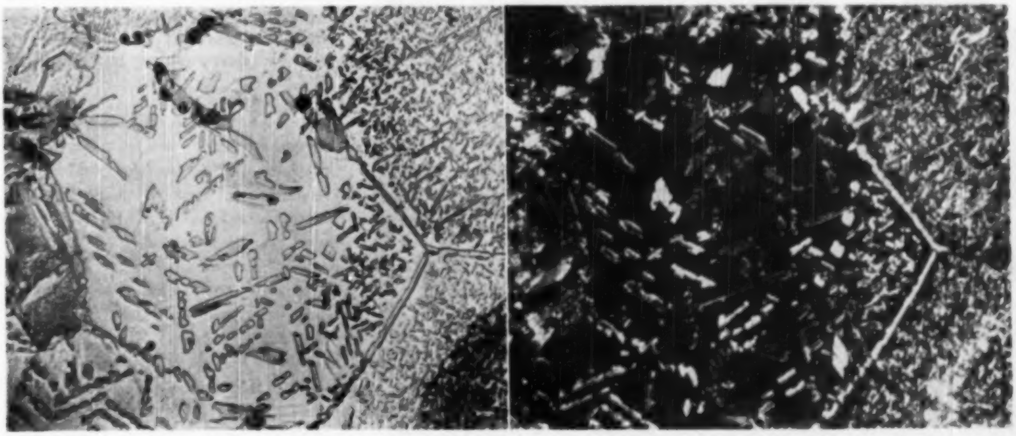


Fig. 1 — Zirconium-Uranium Alloy Containing 22.3% Uranium. Held 6 hr. at 1380° F. and brine quenched. Same area photographed in bright light (left) and polarized light. 250 ×

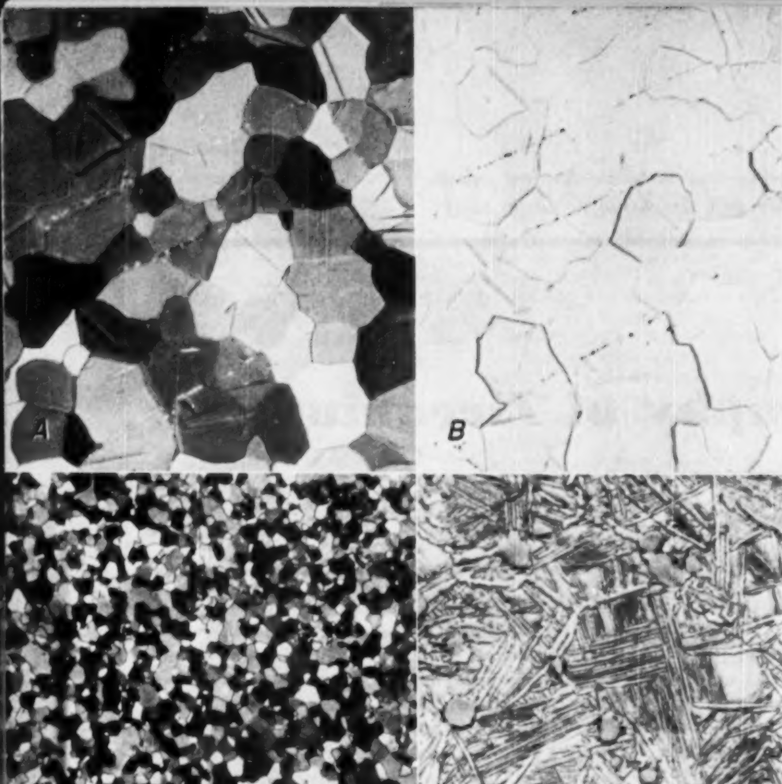


Fig. 2 — All Transverse Sections. (A) "Crystal bar" machined to a round, cold swaged slightly and annealed 2 hr. at 1830° F., subsequently cold swaged to 25% reduction in area and annealed 4 hr. at 1290° F. to recrystallize. Fine carbide stringer formations occur along certain planes within primary crystals. Often such inclusions have a marked effect on new crystal formation and growth in zirconium. (B) Same area. (C) Tubing extruded from cast crystal bar zirconium. (D) Zirconium-uranium alloy containing 19% U with 0.5% C, heated during dilatometric testing to 2060° F. and slowly cooled. The clear, gray globular masses are carbides. Micrographs on left made with polarized light; the other two, with bright light. Magnification 250×, except (D), which is 500×

Most of the zirconium produced in the U. S. is made by two processes, although others have been devised. One reduces zirconium tetrachloride by molten magnesium; this product, as currently made by the Bureau of Mines, consists of a dense sponge. The other process, from which the purest metal is obtained, is the iodide method. Crude powder or lump zirconium is placed in a chamber containing a hairpin filament connected to electrodes. After evacuating and heating, iodine is admitted and the resulting reaction deposits zirconium on the hot filaments. The product is often referred to as "crystal bar", because it appears to be many angular crystals of medium size, haphazardly piled up to form shiny, irregular rods.

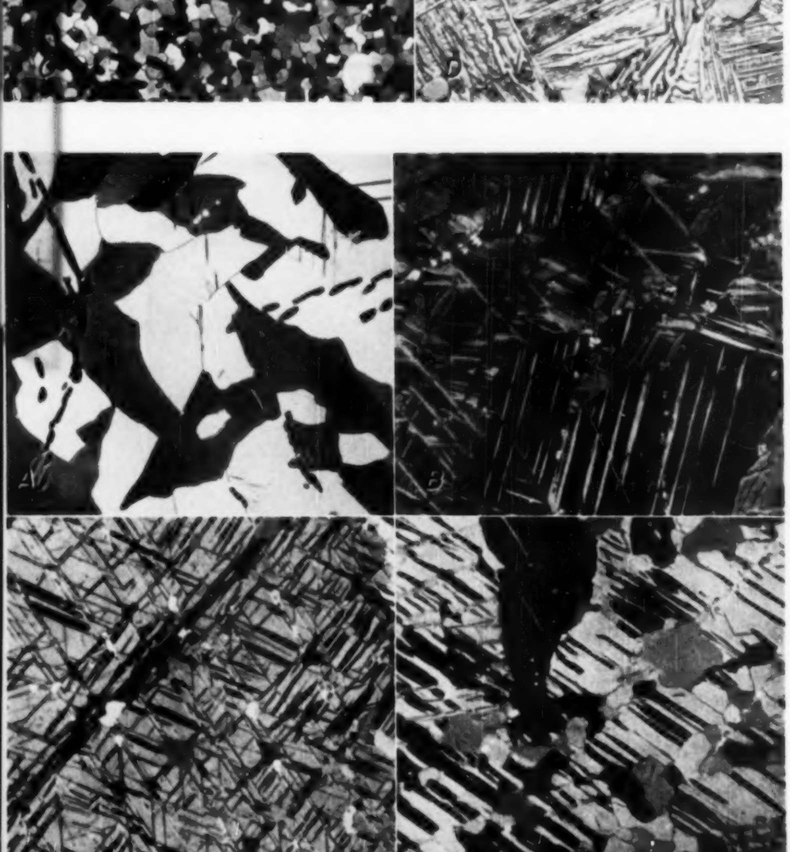
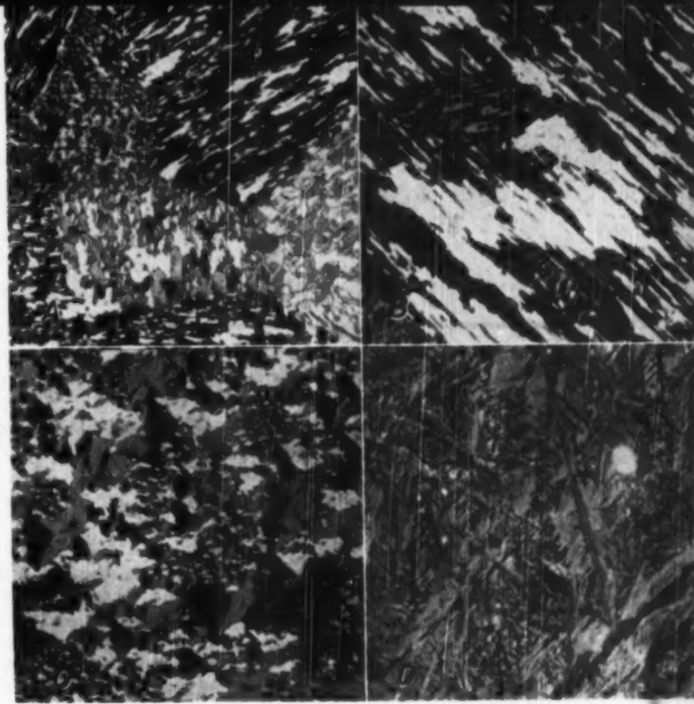


Fig. 3 — Transverse Sections. (A) Bureau of Mines zirconium melted in graphite. (B) Crystal bar swaged to a reduction in area of 6.7%; typical worked structure. (C) and (D) Same metal annealed for 6 min. in lead bath at 1200° F. after swaging. These specimens show recrystallization beginning along deformation bands similar to occurrences observed previously in uranium (see Metal Progress *for November 1949). All micrographs made with polarized light. Magnification 250×, except (C), which is 100×. Prepared for R. M. Treco in an investigation on the recrystallization of zirconium.*

Fig. 4 — Transverse Sections. (A), (B), and (C) are from the same specimen of Foote crystal bar machined to a round, cold swaged slightly to induce recrystallization, annealed 2 hr. at 1830° F. and slowly cooled. Specimen was then reduced 39% by cold swaging, heated to 1830° F. in purified argon and brine quenched. (D) Crystal bar cold swaged to about 20% reduction in area and water quenched from above 1830° F. All micrographs made with polarized light. Magnification 250×, except (A), which is 100×



contact. This also keeps bakelite out of the bath and eliminates the possibility of explosion. (Any reader seeking reassurance concerning the safety of perchloric-acetic acid solutions may refer to the excellent article by P. A. Jacquet, *Metal Finishing*, November 1949, p. 62.)

The electrolyte consists of one part 60% perchloric acid to ten parts glacial acetic acid. This solution can be prepared in a few minutes and used immediately. About 300 ml. total volume is usually sufficient. The life of the bath permits polishing of 30 to 35 samples of approximately ¼ in. square, or about ½ sq.in. of total surface area immersed. Larger pieces can be polished by varying the current density.

The cathode is a strip of stainless steel placed horizontally about an inch below electrolyte surface level. The portion of the sample requiring polishing is immersed with the current on for 45 sec. It is removed rapidly and placed in a mild acetic acid bath for thorough rinsing to remove any accumulated sludge, then rinsed in tap water and dried. The mild acetic rinse consists of 2 to 4 ml. of glacial acetic acid in about 50 ml. of tap water. To polish, about 12 to 18 volts d.c. is used, drawing current within the range 0.02 to 0.5 amperes, the variation depending mainly on the area of specimen immersed. The sample should be agitated during the entire time of immersion.

This procedure should produce an excellent surface for observation by polarized light and often by bright light. It tends to polish some phases and grains of certain orientation preferentially. In some samples this effect may become exaggerated, causing too much "relief" polish, particularly for bright light. Carbides can always be well preserved and polished, unless cracked.

All electropolishing techniques lack exact reproducibility from specimen to specimen. This one has a very narrow working range of current, which must be determined for each sample by trial and error. If the resulting surface has any of the usual undesirable effects of partial polishing, the sample should be immersed for another 30 to 45 sec. If this does not suffice, the sample should be repolished on emery paper and then electrolytically with a slight variation in current.

The condition of the metal has much to do with polishing behavior. Worked structures are difficult to reveal clearly. Cast structures and recrystallized structures produce excellent results. The accompanying micrographs are from samples prepared by the methods described here; none was chemically etched after electropolishing.

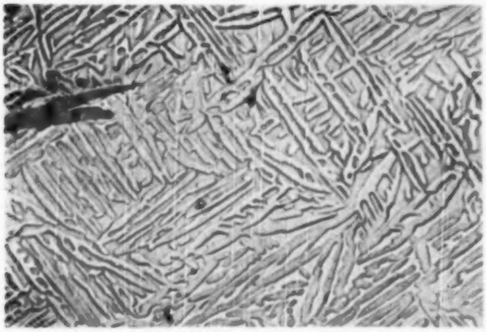


Fig. 5 — Zirconium-Uranium Alloy Containing 15.85% Uranium. Brine quenched after 100 hr. at 1110° F. Carbide appears at upper left as darker gray mass with black voids. Bright light; 250×

Critical Point

By The Editor

White Man's Medicine for Red Man

AMERICAN ORDNANCE ASSOCIATION holds its annual meeting, every three or four years, at Aberdeen Proving Ground, where Army Ordnance officers and men demonstrate the latest guns, ammunition and transport developed for the services, and a breathless show it is indeed. Most notable of the obvious improvements since the Editor's last visit is the waterproofing of the electrical system on all automotive vehicles; a jeep, for example, can ford any creek limited in depth only by the elevation of the driver's nose and the length of the engine's air intake and exhaust chimneys; a standard Patton tank, wallowing through a water hole so deep that only the turret appears, comes out spouting bilge water like a whale, all the time its gun trained on the target by gyro control. Tanks and heavy transport generally are much faster and negotiate almost impassable ground, cross country, rough and swampy. "Power packages" (including 750-hp. engines, transmissions and gear-shifting servomechanisms) are replaceable in the field in 20 min. Armored troop carriers accompany the leading tanks in an attacking battalion; like the trick autos in the circus, they disgorge 24 fully equipped infantrymen. Muzzle velocity of projectiles is greater, which means better ability to pierce armor. Weight is progressively saved in all rifles, howitzers and mortars, big and little, by generous use of higher strength steel, welded components rather than castings, and parts made of aluminum, magnesium and titanium. Many of them can now be air-borne and parachuted. Then, too, there are the unconventional recoil-less rifles, bazookas and rocket launchers — much lighter — some lighter indeed than the round of ammunition, and demountable into subassemblies carried by one man. . . . . Fire power is greater and greater. Twenty-four rockets from a launcher within a minute are impressive enough, but a burst of tracer bullets from the six machine guns in the nose of a jet fighter is really hair raising — 120 a sec. (repeat second!). Even though the plane is on-target but an instant, it is hard to see how anything could fly through such a spray of lead and yet survive. . . . . In the afternoon of this memorable day a mock battle demonstrated how this equipment was used in action. A low hill some 3000 yards away was attacked. It was defended by mythical troops; a half dozen remote controlled tanks and many concealed machine guns and pill boxes heightened the illusion. The area was worked over pretty thoroughly by field artillery, fighters and bombers, and it is hard to see how many humans could have survived, but the enemy tanks then had to be taken care of, and the pill boxes and fox holes cleaned out (some by flame throwers — a nice, civilized gadget if there ever was one!) before the infantry commander radioed "Mission accomplished". . . . . Some Red Korean equipment was trundled past; pretty poor stuff. However, inquiry about the numerous World War II Soviet artillery and tanks on exhibit left the impression that they were stripped of frills, rather rough and ready, evidently made by none-too-skilled workmen, but quite effective weapons nevertheless.

Equipment for the Arctic or the Stratosphere Requires Nonfreezing Lubricants and Shock Resisting Metals (Metals With Very Low Transition Temperatures). Photo by U. S. Army

A New Anodic-Film Method for Studying Orientation in Aluminum

In an earlier article, in *Metal Progress* for March 1948, the authors described a method of surface preparation which revealed, at least qualitatively, the orientation of grains in aluminum. Subsequent improvements in technique may be of interest. This paper will report on the following: *(a)* an electrolyte and technique which give satisfactory results in a shorter time, *(b)* the extended use of striations as a help to observe changes in orientation, *(c)* the application of the method for macro-etching, and *(d)* the application of the method for analysis of flow in plastic deformation and for the study of recrystallization.

Technique — The anodizing electrolyte is mixed in the following proportions:

Orthophosphoric acid (85%)	808 ml.
Diethylene glycol monoethyl ether (Carbitol)	1660 ml.
Hydrofluoric acid (48%)	320 ml.
Boric acid (anhydrous)	128 g.
Oxalic acid (crystals)	72 g.
Water (distilled)	1012 ml.

The ingredients are mixed into the tank and stirred until all are in solution.

The container for anodizing must have chemical resistance and also high thermal conduction so as to transfer heat rapidly from electrolyte to thermostatically controlled jacket. An exploded view of the set-up is given in Fig. 1.

The degree of flatness and polish of the sample is governed by the precision required. Often flattening or polishing is unnecessary. In any event the surface should be clean before its immersion in the electrolyte.

The agitation is controlled in such a way as to have a gentle flow past the sample and yet maintain sufficient flow between tank and central portion of electrolyte to insure temperature control within the limits specified.

Current is derived from a d-c. generator the output voltage of which is so regulated as to procure the desired current density. Normally, less than 40 volts is required; however, if it is desired to smooth out the surface first and to remove a particularly tough oxide skin before anodizing, as high as 70 volts may be required.

The following procedure, at a temperature of $35° \pm 1°$ C., will be found to give a fairly high birefringence combined with clear striations:

1. Step up the current density to approximately 5 amp. per sq.in. for approximately 30 sec.
2. Then drop the voltage until the current density is ½ amp. per sq.in. and maintain at this level for 1¾ min.
3. Remove sample from electrolyte and transfer quickly to cool water. Hot water should not be used for washing and rinsing. Once rinsing is complete, in about 1 min., shake off excess water and dry in a gentle flow of air.

If it is desired to avoid heating of the sample, which may result from Step 1, the voltage should be set at around 30 so as to reach a stable current of approximately 250 milliamp. per sq.in., which is held constant for 5 min. or more, depending on the depth of effect desired.

The procedure outlined above is to give a definite depth of coating and clear striations with

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Kingston, Ontario, Canada

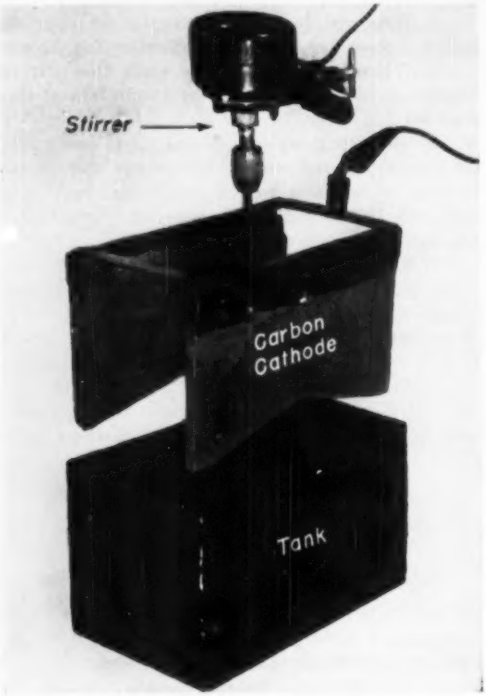
super-purity and commercial purity aluminum. Slight variations of time, current density, and temperature of electrolyte may be necessary with variations of alloy and metallurgical condition.

Applications to Reveal Grain Size

Since the birefringence and direction of striations of the anodic film produced according to the method described above depend on the orientation of the substrate, a very useful application is the revealing of grain size for visual or low-power examination. In Fig. 2 is shown a piece of casting of commercial purity metal which was "macro-etched" as described. Some other alloys have been found to respond quite satisfactorily.

Even very fine grain that is difficult, if not impossible, to reveal by the usual macro-etches may be seen clearly at the low magnifications used for macro studies.

Fig. 1 — Exploded View of Electrolyte Container. Tank itself is made of aluminum sheet, 0.032 in. thick. Cathode is graphite; holes and peculiar shape are to facilitate movement of electrolyte from tank wall to central portion. Chemical protection is afforded by "Nukemite No. 35"



Applications to Plastic Deformation

The gradual change of orientation in a deformed structure may be readily followed by the change in interference colors and by the change of direction of the striations. The manner in which plastic deformation distorts the structure is shown in Fig. 3, 4 and 5.

In Fig. 3 is shown a piece of super-purity aluminum sheet with 0.11% silicon added which was given a reduction of 75% and subsequently annealed for 30 min. at 600° F. Only partial recrystallization has occurred. The parts that have remained unrecrystallized still show the

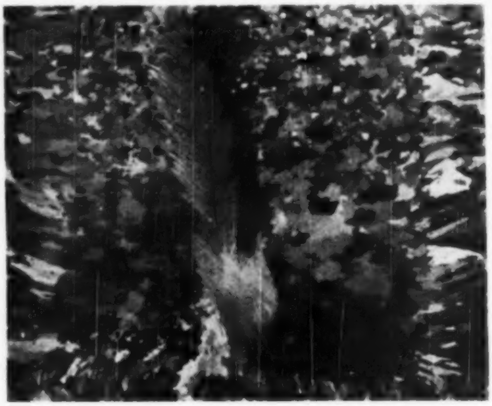


Fig. 2 — Grain Size in a 4 x 4-In. Area of Casting of Commercial Purity Aluminum

changes of orientation within one grain caused by plastic deformation.

Figure 4 shows a similar piece of metal at a higher magnification to reveal the detail of the banded grain shown in Fig. 3. In this specimen parallel portions of the grain have rotated in a manner suggestive of twinning.

In Fig. 5 is shown another similar piece of cold worked super-purity metal exhibiting two other types of deformation occurring within one grain. In one type, where the striations are straight, apparently only slip has taken place, with little or no relative rotation from region to region of the same grain. In the other type, deformation has taken place with some rotation. It should be noticed that some grains and portions of some grains receive much more deformation than others if the amount of rotation is taken as a criterion of the amount of deformation. The additional information given by a color micrograph can be

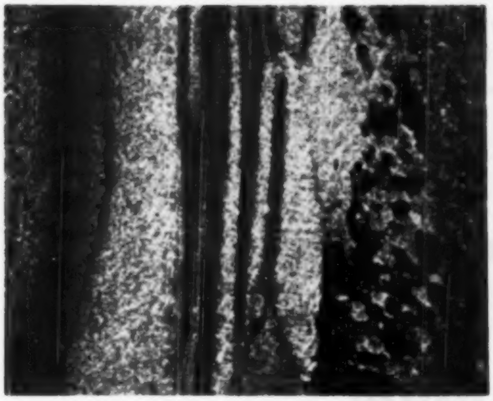


Fig. 3 — Partially Recrystallized Super-Purity Aluminum Sheet With 0.11% Silicon Added. In some regions a cold worked structure still prevails, whereas in other regions recrystallization has started. Of particular interest are the parallel bands in a single deformed grain and the similarity of orientation of a group of new recrystallized grains in a single grain. 100 ×

Fig. 4 — Detail (at a Magnification of 500 Diameters) of Parallel Bands in Middle of Field of Fig. 3. From the striations it may be seen that adjacent bands have widely different orientations and that within one band and near the band boundaries there is a gradual change of orientation. Parallel portions of the grain have rotated in a manner suggestive of twinning

judged by comparison of the black and white rendition, Fig. 5, with its color reproduction on the front cover.

Applications for the Study of Recrystallization

By the study of orientations and deformations some light may be shed on the structural changes that take place when a deformed piece of metal is subjected to a thermal treatment for purposes of softening. As an example of the type of information that is obtainable, several features may be analyzed from the structure shown in Fig. 3. The field referred to is the region where recrystallization has started, toward the right-hand side. From it may be deduced:

1. Recrystallization does not occur homogeneously throughout. Some regions of a piece will recrystallize partly, if not wholly, before others.

2. Recrystallization is often observed to start at preferred locations such as grain boundaries or near grain boundaries, or in certain parts of one grain that have been subjected to a different deformation because of the pressure of surrounding grains.

3. At temperatures near 535° F. (the phenomena at other temperatures have not been studied yet) the new grains forming within a uniform region of a single deformed grain take up a common orientation which is different from the orientation of the deformed matrix. This common orientation is strikingly revealed by the original micrograph taken in color, in which all the recrystallized grains show the same color.

Fig. 5 — Cold Worked Super-Purity Aluminum Sheet. The grain on the extreme left has been homogeneously deformed whereas the two others have suffered some torsional flow. 500 ×. Color micrograph of this area is shown on the front cover of this issue of Metal Progress

This article describes the operation of induction furnaces for melting titanium in graphite, the mechanical properties of the as-cast metal and its forging characteristics.

Casting and Forging of Titanium

THE FIRST YEAR of Du Pont's development work on titanium was summarized in *Metal Progress* for February 1949, p. 195. At that time facilities had just been installed for induction melting and casting 100-lb. ingots in graphite. During the last year, the scale of operation has been gradually increased until 650-lb. ingots are now being cast regularly by the same technique. Several thousand pounds of titanium have been melted in the furnace represented in Fig. 1.

Basically, the furnace consists of a graphite melting pot (1) (CS-grade graphite) insulated by carbon black from an exterior silica or transite shell (2). Shell temperatures do not exceed 400° F. and transite is preferred because of mechanical stability and lower cost. A short pouring spout is threaded into the bottom of the melting pot and feeds into a removable graphite liner (3), surrounded by a permanent graphite sleeve (4). The metal pours through the liner into a graphite mold (5) provided with a removable plug (6). The mold is held in place by a mechanical jack (7) to facilitate assembly. The melting crucible is supported by porous carbon blocks (8) which, in turn, are supported on a 1-in. transite plate (9). Threaded hangers (10) from aluminum angles (11) support a graphite mold lid (12). The density of sponge does not permit holding of the entire charge (650 lb.) in the melting crucible, and a hopper (13) equipped with feed rods (14) and sight glasses (15) is employed. Sponge flows from the hopper through a steel tube (16) into a graphite pipe (17). A poke rod (18), centered by a graphite bushing (19), is necessary for measurements of sponge depth and may be used for clearing the pouring spout. Energy is transmitted to the crucible by a water-cooled copper induction coil (20) powered by a 100-kva., 9600-cycle motor-generator set. Tapping is accomplished by fusion of a titanium plug inserted in the pouring spout. A secondary water-cooled copper coil (22) provides the necessary energy. Temperature measurement, based on optical pyrometry, is made by sighting on the bottom of blind, argon-flushed tubes (21) located in the wall and center of the melting crucible. Argon is introduced to the melting crucible, mold, and hopper (23) and vented (24) through the transite lid (25). Pressure is relieved during casting by an expendable rubber balloon (26).

A typical cycle consumes about 10½ hr. for a 450-lb. ingot, consisting of the following steps:

1. Charge sponge to crucible and hopper.
2. Flush 2 hr. with 8 cu.ft. of argon per hr.
3. Initiate power to the primary coil (20) to 25 kw. for 1 hr., during which time furnace temperature reaches about 1650° F.
4. Boost power input to 40 kw. for next 2 hr.,

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and William B. DeLong
Engineering Research Laboratory, Wilmington, Del.
E. I. du Pont de Nemours & Co.

at which time the charge will have settled to one half its original volume.

5. Initiate hopper feed; charge level is maintained relatively constant by means of poke rod measurements.

6. Add feed intermittently for the next 5½ hr. and regulate power so that the crucible wall temperatures do not become excessive (3140° F. max.).

7. When the entire charge is molten, energize the tapping coil and drop the melt. If necessary, the poke rod is used for clearing the spout.

8. After cooling 6 to 8 hr., open apparatus and discharge ingot.

Pertinent data on a 450-lb. melt are:

Total cycle	10½ hr.
Pouring temperature	3150° F.
Energy input	274.1 kw-hr.
Energy per pound	0.609 kw-hr. per lb.

Shrinkage on solidification is about ½-in. on the diameter of a 16-in. ingot, allowing for easy removal from the mold. Surface is good, as was illustrated in Fig. 1 on p. 190 of *Metal Progress* for August 1950.

In contrast to what occurs to many metals, titanium ingots do not pipe, probably due to the presence of hydrogen, which approximates 0.006% in both sponge and ingot. In fact, a negative pipe or top bulge results.

The hydrogen may collect in small pockets, forming an envelope not unlike rimmed steel; this phenomenon is shown in Fig. 2. The ingot was polished and etched with dilute nitric-hydrofluoric acid and india ink was used to improve contrast. The macrostructure shows a thin skin of fine equiaxed grains which formed as the molten titanium was chilled by the relatively cold graphite, followed by an envelope of blowholes, 1½ to 2 in. wide.

Fig. 1 — Induction Furnace

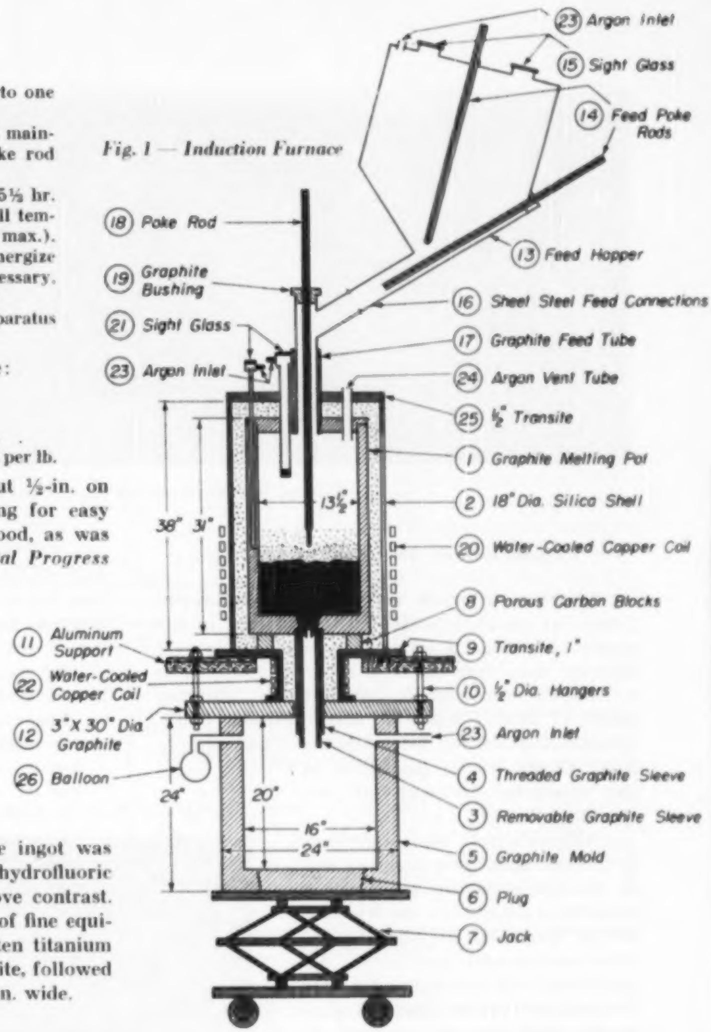


Fig. 2 — Section Through a "Rimmed" Titanium Ingot, 8 In. Across Top

Columnar structures can also be produced at lower cooling rates, as shown by the 400-lb. ingot in Fig. 3, p. 718. This solidification condition apparently minimizes blowholes. A fine equiaxed exterior is noted, followed by columnar grains exhibiting directional solidification; medium-sized equiaxed grains are shown in the ingot center.

Ingots produced by induction melting of sponge titanium usually contain 0.4 to 0.8% carbon and 0.02 to 0.06% nitrogen. Brinell hardness is in the range from 200 to 250.

Alloys are easily prepared in this type of furnace, and ingots containing as much as 35% aluminum, chromium, iron, manganese, and nickel, with the remainder titanium, have been cast without difficulty. Because the entire charge is molten, there is no abnormal tendency for segregation or "layering" of the alloying constituents. Pouring temperatures are usually lower, and carbon pick-up can be held to 0.5% or less in some alloys.

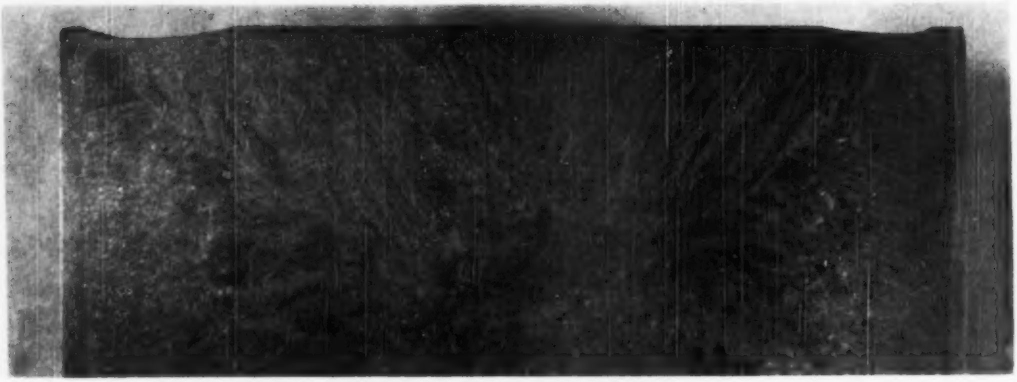


Fig. 3 — Typical Macrostructure of Ingot Measuring 13 In. Across

Properties of As-Cast Titanium

Contrary to many reports, good mechanical properties can be obtained with titanium in the as-cast condition. A series of specimens of several different sizes were cut from different positions in a 7-in. diameter, 100-lb. ingot of the following analysis: 98.48% titanium, 0.98% carbon, 0.06% nitrogen, 0.05% iron. Table I, at top of the opposite page, shows tensile properties at two positions for each of two specimen sizes.

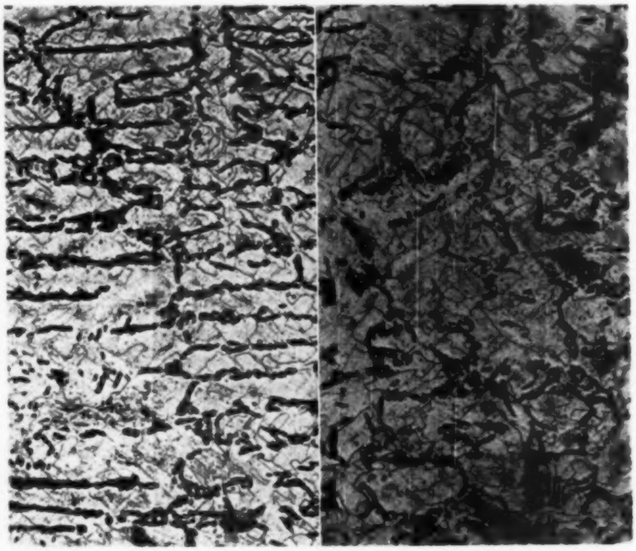
Although there was a difference in fracture grain size, probably due to the variation in solidification conditions between the top and bottom specimens, the tensile properties were roughly equivalent. All specimens exhibited the familiar "orange peel" surface along the gage length, indicating homogeneity of the material and lack of local defects.

Oriented dendrites were observed in these specimens and fracture tended to take place parallel to the dendritic trunks. Even with such unfavorable orientation, 7 to 8% elongation in 2 in. was achieved. The association of carbide chains with transformed beta dendrites is clearly demonstrated in Fig. 4 at right.

The typical top-bulged surface represents an interesting ingot structure. Oriented dendrites perpendicular to the top surface indicate that freezing occurred prior to complete center solidification (top of Fig. 3), and it is postulated that rejection of hydrogen in the molten center displaces the top upward. [Editor's Note: Swelling of cast slabs of copper and its alloys is such an abstruse phenomenon that the real reason may be obscured.]

Other cast alloys prepared by arc melting have shown elongations of 15 to 20% in 2 in.

Fig. 4 — Fracture Surfaces of 0.250-In. Tensile Bar. 100 ×



Parallel to fracture directionality

Perpendicular to fracture directionality (end view of dendrites)

Table I — Tensile Properties of As-Cast Titanium

Position	Specimen Diameter	Tensile Strength	0.2% Yield Strength	Elong.	R. A.
Top, radial	0.505 in.	92,000 psi.	81,500 psi.	7.0%	9.5%
Top, radial	0.250	96,800	87,900	7.0	7.1
Bottom, radial	0.505	94,400	83,000	7.5	9.0
Bottom, radial	0.250	98,400	88,000	8.0	7.0

Forging

As was reported by J. Maltz and V. DePierre of U. S. Naval Gun Factory in *Metal Progress* for August, the forging of commercial titanium containing 0.78% carbon offers no special difficulty; the metal flows more readily than mild steel at the same temperature. These experimenters used the ordinary heating and forging techniques found in drop forging shops making steel parts. Their work included hammer forging between flat dies, hot rolling in a plate mill, and drop forging into small levers.

Table II — Effect of Forging Temperature

Temperature	Forging Blows*	
	Run A	Run B
1600° F.	45	36
1700	21	22
1800	18	19
1900	16	17
2000	15	16
2100	17	15

*Number of blows to reach a constant deformation.

Commercially pure titanium containing about 0.7% C flows freely in the temperature range 1800 to 1500° F.; higher temperatures do not increase forgeability much, as can be seen from the data in Table II, developed in cooperation with the Wyman-Gordon Co. The constancy of the delivered blow in these tests depended on the operator's skill and was not mechanically controlled.

After forging, hardness transverses were made along the center line of a slice cut from each disk. All samples showed a uniform hardness of about 240 Vickers, excepting the sample forged at 1600° F., which tested 273 Vickers, probably due to cold work. The 1600° sample also exhibited a higher tensile strength, as can be seen in Table III.

Microhardness surveys showed a maximum depth of hardening of 0.020 in. on the piece forged at 2100° F. This hardened layer was found on the portion of the disk that had rested on the cold anvil during forging and probably represented the maximum depth of hardness penetration during heating. It was found that the hardened zone or layer penetrated to an extremely shallow depth on the upper surface of these disks, indicating that the hardened layer probably broke off during forging. No hardened layer was found on the piece forged at 1600° F.

Table III — Mechanical Tests on Upset Forgings

Forging Temperature	0.2% Yield Strength	Tensile Strength	Elongation	Vickers Hardness*
1600° F.	106,000	112,000	10%	273
1700	92,000	100,000	8	237
1800	86,000	99,000	10	240
1900	85,000	96,000	12	239
2000	85,000	98,000	17	230
2100	81,000	95,000	16	241

*Average across sample.

Fig. 5 — Cross Section of Forging After 80% Reduction. Unetched; 50×

Voids in titanium appear to be satisfactorily welded by simple forging. Forging tests on an ingot containing numerous voids sealed completely after 50 to 80% reduction in cross section area. This is shown by Fig. 5, illustrating the microstructure after 80% reduction. No holes or lines are observed which would be indicative of simple flattening of the voids without welding, and tensile tests on the forgings showed normal values. The fact that welding is obtained between titanium sheets pack-rolled at 1450° F. is further evidence for this conclusion.

Typical cast and forged structures for a titanium ingot containing about 0.8% carbon are shown in Fig. 6. The dendritic carbide pattern is readily apparent in the as-cast metal. On forging, the dendritic structure is replaced by a random distribution of rather small rounded carbides.

As Cast Forged

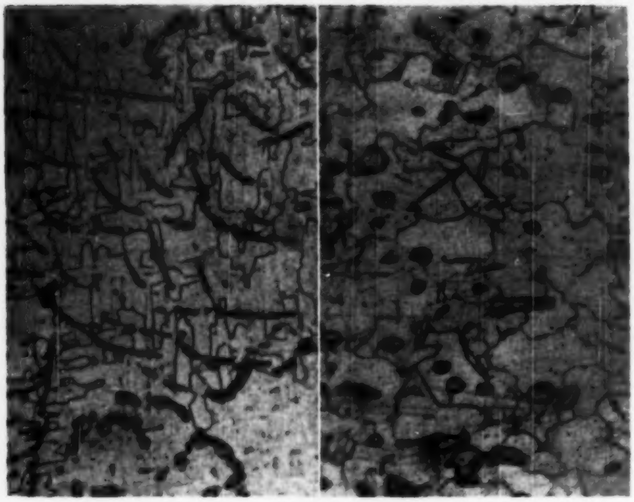


Fig. 6 — Carbides in Titanium Containing 0.8% Carbon. 250×

Similar results are obtained with more complex alloys. The as-cast and forged structures of a 3% Al, 5% Cr, 0.5% C alloy are shown in Fig. 7. Again dendritic carbides are well broken up on forging. The dark-etching constituent, which is acicular alpha phase, seems to be concentrated around the carbide particles and grain boundaries, indicating that the beta-to-alpha transformation started at these regions as the forging cooled.

Hardness

The hardness of titanium and its alloys can be applied in many cases as a rough measure of strength and ductility. Since all of the conventional hardness scales are being used, several series of comparative measurements have been made relating the Brinell, Vickers, and Rockwell A and C scales. These data, based on numerous measurements on over 50 samples of forged and rolled material, are plotted in four drawings on data sheet on p. 720-B. Another graph at the center of the sheet shows the relation between tensile strength and hardness for a series of rolled strip specimens of iodide, arc-melted, induction-melted and titanium alloy. It is obvious in this graph that the tensile strength of iodide strip and annealed strip is proportional to the Vickers hardness number (10-kg. load). Strength of forged and air cooled forgings is also proportional to hardness, but the ratio is somewhat larger.

Conclusions

A commercially feasible method of casting titanium ingots up to 650 lb. has been developed. Such ingots are homogeneous and contain as the primary impurity about 0.4 to 0.8% carbon. Complex alloys have been prepared without any apparent segregation.

The structure of titanium ingots is sensitive to pouring temperature and rate of solidification. Porosity which occurs in some ingots is apparently eliminated by welding during forging. As-cast titanium shows appreciable ductility.

Conversion curves relating various hardness scales for titanium have been prepared.

As Cast Forged

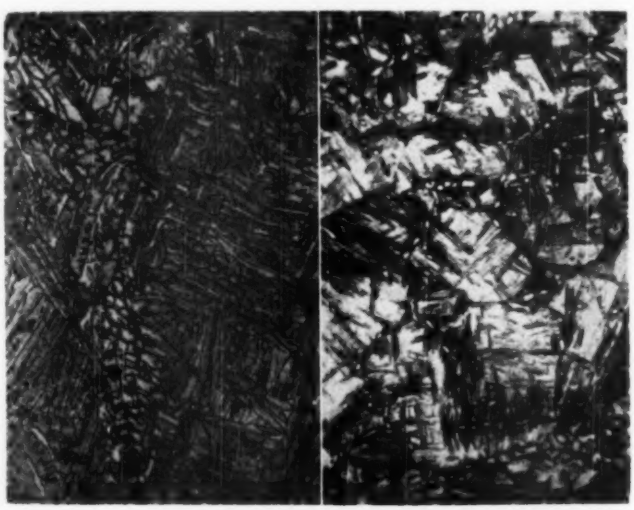
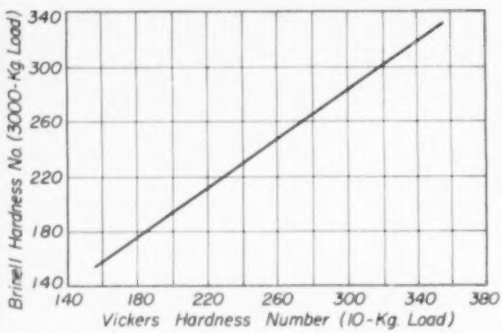


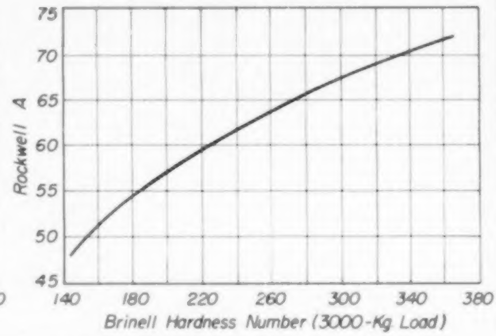
Fig. 7 — Carbides in Titanium Alloy Containing 3% Aluminum, 5% Chromium, 0.5% Carbon. Dendritic carbides are well broken up on forging. 250×

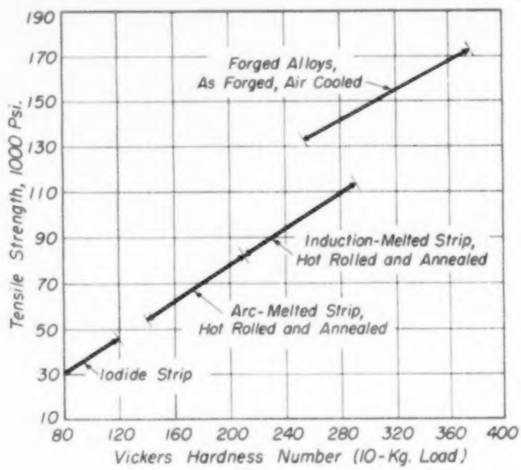
Hardness Conversions for Titanium
and the Relation Between Hardness and Tensile Strength

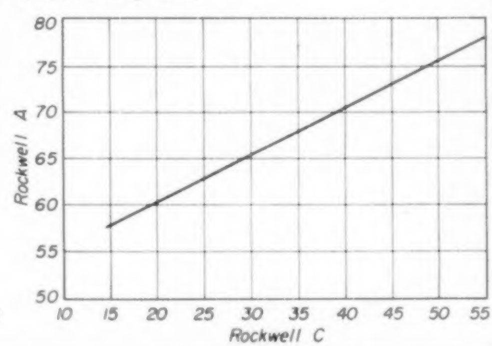
Compiled by J. B. Sutton, E. A. Gee and W. B. DeLong

E. I. duPont de Nemours & Co., Inc.









Tests show New Quench Oil has Intensified Triple Action

● A new accelerated quenching oil has been developed that gives (1) rapid heat removal with faster cooling rate in the hardening range, this results in higher and deeper hardness; (2) slow cooling below the hardening range, thus minimizing distortion; (3) greater stability due to special anti-oxidants, for longer life and bright quenching properties.

To better illustrate the manner in which this triple action quenching oil accomplishes this higher quenching efficiency, it will be well to show the three stages of cooling as observed when steel is quenched in oil from a red heat. These stages are:

A. Formation of a vapor film at the steel surface; cooling is accomplished by conduction and radiation through this vapor film and is relatively slow.

B. Direct contact of the oil with the metal surfaces, causing a boiling action which continually dissipates the vapor film formed and results in rapid cooling.

C. After the metal has been cooled to the boiling point of oil, vapor is no longer formed; cooling is by conduction and convection, and the metal slowly cools to the temperature of the oil.

It is apparent that any improvement in the cooling power of oil in stages A and B would be most desirable. This can be compared to the brine quench which is used instead of water. Brine has a wetting action that completes the quench faster than fresh water, which "takes hold" only in spots, causing non-uniformity. Salt brine solutions provide deeper and more uniform hardnesses. This results in deeper and more even hardnesses. It seems logical to attempt to do this same thing with oil. The mineral intensifiers added to this Triple A Quenching Oil act in this manner.

Practical Application of Quench Curves to Hardening Steel

The improvement of oils so as to effect this desired change in the cooling characteristics has been attempted in the past by blending mineral oil with animal oils, but the product was prone to become rancid, or to decompose on contact with hot steel. These blends were also unsatisfactory as quenching mediums for steel treated in certain types of salt baths.

Developed in the Research Laboratory of the Park Chemical Co., the Park Triple A Quench Oil, a blend of specially refined mineral oils, cools steel faster in the upper temperature range by shortening the duration of vapor stage (A) and intensifying the action of boiling stage (B). Heat removal in stage (C) is slow and uniform. Thus, the best surface hardness and depth of hardness penetration are achieved with no danger of cracking or distortion.

Extremely stable, this new accelerated quenching oil may be used as a quench from any heat treating medium without fear of rancidity, oil breakdown, or change in quenching efficiency. Further, Park Triple A Oil is especially suitable for obtaining the maximum uniform oil-quenched hardenability from low and medium alloy steels.

Results of the improvement are shown in chart below showing actual hardnesses in quenched pieces. There is a 16% surface hardness increase with Park Triple A Oil over a good grade of straight mineral oil. The effect would be greater when comparing it with some of the poorer grades of oil used for quenching. Center hardnesses of the one-inch diameter piece are up 14%. Lighter sections would show even more increases.

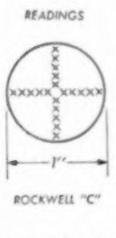
Bright Quenching and Stability

A very crucial and costly problem in the carbo-nitriding process has been the cleanliness of work after oil quenching. Oils which deteriorate rapidly or were originally unsuitable leave a sooty carbonaceous film on the surface of the work. This presents a difficult cleaning problem when followed by a plating or welding operation.

This difficulty, when not the fault of the furnace atmosphere, can be corrected by the use of Park Triple A Quench Oil.

Through the use of anti-oxidant additives and mineral intensifier it has been possible to prolong the bright quenching properties of good clean oil. Underwood Oxidation experiments have proven Park Triple A Quench Oil to have exceptional stability and long life.

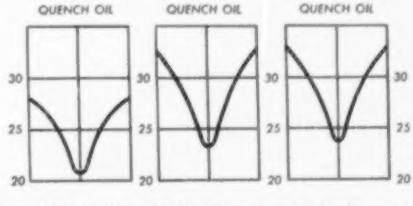
A Bulletin, #F8, was prepared on Park's Triple A Quench Oil. It gives you a complete description of this oil with cooling curves, production data and photographs. Write Park Chemical Co., 8074 Military Ave., Detroit 4, Mich.



STEEL: S.A.E. 1045 1" ϕ x 2"

TREATMENT: 1550° F. IN NEUTRAL SALT QUENCH IN OIL AT 75° F.

HARDNESS: ROCKWELL "C" READINGS ACROSS INNER SURFACES OF SECTIONED SAMPLES



Transverse hardness Rc taken on 1" round SAE 1045 steel two inches long. Quench from Park's Nu-Sal neutral salt at 1550°F. into three types of quench oil, Park's No. 100 Oil (straight paraffin), Park's "S" Oil (compound with animal oil), Park's Triple A Oil. Oil temperatures 75° F.

In the Campbell Memorial Lecture, Mr. Smith vivaciously draws a parallel between the impediments that all but discouraged such early ironmakers as Dud Dudley and the regulatory measures in today's socialistic and welfare states. Acknowledging that the blast furnace is not an efficient machine, he then discusses several methods for improvement. Metal Progress *is able to use only about 15% of the entire text, which will be published complete in* ⊕ Transactions.

Iron Smelting Problems

I MAKE A DIRECT REQUEST, as a friend of the blast furnace men, that we get acquainted with at least some of their problems, which are by no means limited to technical difficulties. In considering some aspects of the modern problem in the background of medieval times, we find that Biringuccio in 1540 wrote chapters on iron smelting which are better records of his day than exist to describe our early American furnaces. With but slight modification the chapter on iron ore could describe today's situation. The business is bigger but the problems have not changed.

Our own records are far from complete. It may be that present-day operators of blast furnaces only carry on an age-old tradition that iron is important, skill paramount, and records incidental.

Table I — Commercial Iron Ore Reserves in U. S. (1950)

Region	Average Grade	Gross Tons
Northeastern	60% Fe	1,600,000,000
Southeastern	35%	1,100,000,000
Lake Superior	51.5%	1,600,000,000
Western	50%	800,000,000

In any process which depends upon the skill of the operator and where the moves are carried out on a trial basis, the record is always of secondary interest. There remains the fact that our science has not provided the blast furnace man with a road map.

Iron Ore — The byproduct coke oven, the Mesabi ore discovery, the use of basic openhearth steelmaking, and the Duquesne blast furnace combined to increase the steelmaking capacity. Steel plants were built near consuming markets without regard to adequate transportation of ore and coal, and now, in less than two generations, we find the blast furnace man wondering what ore he will be using next season.

It is impossible for me to agree that we are nearing the end of blast furnace ore in North America. (See Tables I and II, from data of U. S. Geological Survey.) The lowest iron content ore that I have observed in commercial blast furnace was used at Scunthorpe, England, during 1942. The actual local ore with 16% iron was combined with comparatively rich Corby ore which had 29% iron. These excellent furnaces with outstanding performance records are leading the way in carbon lining for big furnaces. If this country ever gets humble enough to quit crying and go to work we need not use any 16% iron content for several hundreds of years. The coke blast furnace is a flexible tool in industry. It is effective — not necessarily efficient. What it can actually use has never been clearly established.

Linings — Blast furnace firebricks, the resultant of some hundred years of trial and error, represent the blending of different clays. The usual combination consists of a clay with good refractory properties and indifferent bonding qualities mixed with another clay that may have mediocre refractory properties but excellent bonding ability. The

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Republic Steel Corp., Cleveland

Table II — Active Foreign Iron Ore Interests

Country	Grade	Approximate Reserves	Interested Company
Chile	55%	105,000,000	Bethlehem
Liberia	66%	15,000,000	Republic
	42%	110,000,000	
Venezuela			
Cerro Bolivar	High	1,000,000,000 +	U. S. Steel
El Pao	60%	60,000,000	Bethlehem
Canada			
Labrador	60%	400,000,000	Iron Ore Co. of Canada
Steep Rock	55%	280,000,000	U. S. and Inland
Michipicoten	35%	100,000,000	Jones & Laughlin

whole business, the exact particle size of each clay, the amount of ingredients, the molding, drying, burning, inspection, and shipping, is a mixture of art, science, skill and commerce.

Since a blast furnace hearth is expected to be in service many years, special masons, moving from company to company, lay the brick. The furnace operator uses the best judgment and skill available in blowing in the furnace. In spite of all known precautions we have significant variations in the same furnace with different linings from the same brick company, with everything as nearly identical as customary testing could determine. In recent years a lining in a furnace lasted one week. Another furnace, after a full campaign, still had a hearth so nearly perfect that the salamander iron was less than 100 tons. That is the blast furnace man's major problem in its nasty aspects. He is expected to get at least 2,000,000 tons of iron or more production from a hearth.

The brick that failed prematurely showed upon examination that internal fissuring in the brick permitted iron to penetrate the fissures. Molten iron is not a very sturdy bond for the flint clay particles which make up the real body of the brick. Such failures, although very rare, explain in part why the European blast furnace men risked carbon blocks in their hearths and the reason behind the present experiment with carbon hearths in the United States. The Thomas basic bessemer process of Europe requires an iron, high (2%) in phosphorus, that is more fluid than the lower phosphorus irons we use in American steelmaking. Hearth breakouts were more of a problem in blast furnaces making such fluid iron.

There have been several quite serious failures with carbon hearths in the United States and some of these failures have not been adequately explained. Personal observations indicate no problems impossible of solution. The working face of carbon-lined hearths has given little trouble. (Saw cutting marks have been observed on carbon blocks in a hearth after making hundreds of thousands of tons of iron.) Trouble has occurred at the iron notch area; wet notch clay and resultant steam destruction are the probable explanation. Damage to the blocks away from the working face has been explained by oxidation from steam as a probable cause, along with oxidation due to air infiltration. While we provide a tight brick outer shell, and attempt to prevent access of air to the hot carbon, we are more concerned about leaking water near the hearth.

The carbon hearth may have arrived at the proper time. After studying the probable ore supply for future ironmaking in the United States one can anticipate less alumina for the slag systems involved. In at least two recent hearth breakouts the lack of alumina (9 to 10% Al_2O_3 slags) caused the furnace to slag the lining to satisfy the need for alumina. As in many other industrial moves, the accessory protection of the non-slagging carbon block may well be more important than the primary saving visioned at the time of installation.

A modern turboblower for a blast furnace may be said to be able to deliver 100,000 cu.ft. of air per min. at 30 to 35-psi. pressure. Normal operation requires a blast that exceeds the approximate 18-psi. pressure drop through the stack by enough to force the gas out of the furnace through

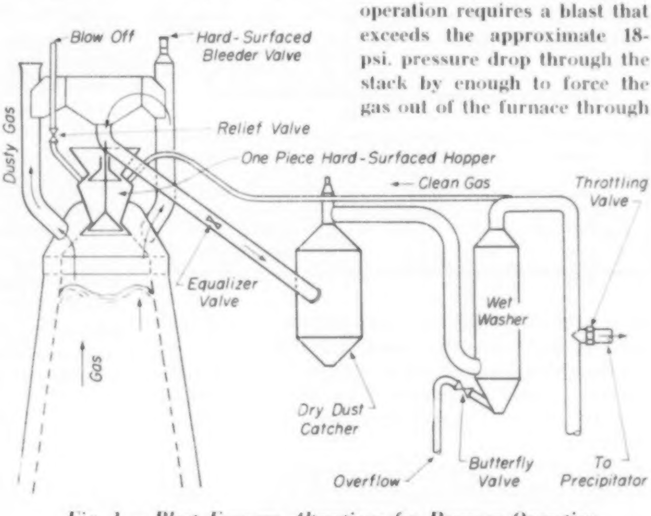


Fig. 1 — Blast Furnace Alterations for Pressure Operation

the cleaning and into the gas system. Pressure at the top of the furnace is about 2 psi.; furnaces that are being pushed rarely exceed 4 psi. at the top. There are many operating reasons why this pressure has not been exceeded, but the most important is excessive dust loss.

Pressure Operation

High-pressure operation of blast furnaces was developed under the invention of Julian Avery. In 1938 Avery, then with A. D. Little Co., suggested that pressure operation at one or two atmospheres above normal be achieved by controlling the outflow of gas. His invention concerned the automatic throttle valve at the outlet (see Fig. 1). As no furnace was equipped to carry such pressure, the demonstration awaited the war with its shortage of iron which justified the trial.

The Defense Plant Corp. furnace, adjacent to the Cleveland plant of Republic Steel Corp., was operated by our blast furnace group under J. H. Slater, whose untimely death before this development was fairly started deprived the industry of one of this generation's most capable men. The general foreman of this furnace, Walter Montgomery, has been with this operation since the start.

Cost calculations indicated that the furnace could be pushed with Lake ore until the dust loss exceeded 350 lb. of dust per net ton of iron. Such an operation did not require any change in the structure. Top pressure operation required turboblowers in series and regulator valves in the gas main behind the washer.

Although such early operation under the observation of War Metallurgy Committee indicated an excellent normal operating stack, pressure operations brought on a series of problems. Numerous gas leaks caused damage by grit blasting. Gas washer seals were inadequate. The new pressure regulating device was not well understood. When the furnace was finally able to operate, it was found that dust loss was very small — also that the furnace could handle the additional wind without getting rough in operation.

Joe Slater and Walter Montgomery, who had pushed the furnace during normal operating experiments to establish an upper limit of wind regardless of dust, were satisfied that less than 90,000 cu.ft. per min. of wind could be used with straight Lake ore burden. Mr. Slater's most important criterion of test was simple: "Would the furnace settle down and drive smoothly when higher wind and top pressure were tried?" Blast furnace men are by nature determined people. Before Slater died, he and Montgomery had blown 110,000 cu.ft. of wind per min. with 11-psi. top pressure and had a smooth furnace on straight Lake ore.

The first lining finished its usefulness early in October 1950, and finally the first chapter of its history can be written. We know we can operate for normal periods of time. Republic Steel Corp. will provide additional furnaces as we can afford the equipment cost.

We have behind us the actual operating experience. We have before us many problems, such as better methods of stopping gas leaks (grit blasting). Bell and hopper wear have been brought under control by equalizing the pressure between the bells with cleaned gas. Lining erosion, always a problem even in a normal furnace, does not seem to be any different in pressure operation.

We have not yet had an opportunity to study some rather interesting problems such as optimum size of limestone, coke, charging sequence, proper top temperature, blast heat for various burdens, the proper type of sinter and even the transportation problems that arise with increased production.

We have not explored the higher top pressures — that is, above 12 psi. — because of limitations of furnace construction. (One instance of faulty welding in a dust catcher top showed up as we increased the pressure.) We will have to feel our way into new methods as we equip more furnaces and develop structures to handle the higher stresses.

Earle Clement Smith

HIS PERSONAL INTEREST in blast furnaces, he says, "started 50 years ago when I burned a bare foot exploring the mysteries of a cast house in New Castle, Pa." Educated at Ohio State University and by U. S. Army Ordnance, he has been with Republic Steel Corp. or its predecessors since 1919, for 13 years in operating positions and since 1932 as chief metallurgist of the corporation, wherein he exercises his almost encyclopedic knowledge of all phases of steelmaking, plain and alloy.

Gas Studies

Studies and calculations concerning blast furnace gas have gone hand in hand with furnace development. Sampling has been an outstanding

problem; analysis of the gas is not particularly difficult; interpretation of results is as variable as the schools of furnace operators. The Bureau of Mines' studies of some years ago furnished a mass of well-handled measurements. Interpretation of these data is still a matter of personal opinion. The present interest in gas study is important because of the relative increase in coke cost and operating expense. (Ore and transportation costs have also gone up but not in the same proportion as coke cost.)

Efforts to correlate the known variables for which data are obtained fall far short of the need since they do not include the *reducibility* of the iron ore. It has been known for hundreds of years that limonites, hematites and siderites reduce with less trouble than magnetite. In Biringuccio's time the magnetites were not considered "ore" in that area, even though the Swedish furnaces had solved the problem of reduction of magnetite many years earlier. Dense hematite ores were known to be difficult to reduce unless crushed to small particle size. Reduction studies to arrive at some measure of reducibility have been made in many laboratories. There have been many full-size furnace runs which give gross figures. All these tests are useful to the furnace operator but none permits him to burden his furnace except on an empirical basis. [In his presentation Mr. Smith had many slides showing the different characteristics of the iron oxide in many commercial ores, and the different grain sizes and methods of agglomeration in various pellets and sinters.]

In our studies in Cleveland it has been determined that several hours elapse between significant changes of top gas chemistry and the corresponding changes of analysis of the iron, despite the fact that the British experiments with radon tracers indicate but a few seconds travel time for gas.

Furnace performance changes slowly. Five hours after the gas warning, the iron from the furnace at Cleveland gives confirmation. During that period we can make changes in the operation such as higher blast heat, change of burden. The dramatic way that a water leak of consequence shows, permits repair to be undertaken in minutes. The major burden changes still require hours. Extra coke at the top is seven hours ahead of significant gas changes. Wind rate changes show very quickly because of altered CO/CO_2 ratio. The combination of this work and Walter Montgomery's utilization of the information has produced much more uniform analysis iron. Our best test period was one in which he predicted correctly his cast conditions over 80% of the time and his operating changes hours in advance, thus resulting in many more casts of iron of desired chemistry.

Blast Furnace Comment

In a letter about a year ago from a man who does not think the big blast furnace is anything to be worshipped, he says:

"The blast furnace is not efficient, and under existing circumstances can scarcely be a money maker, provided the bookkeeping is honest. It has but one virtue — size. It is an affliction sent on the industry for reasons not yet understood."

With the comment that the blast furnace is not efficient I can agree but the critic forgets that every day we are willing to give ground technically for effective economic performance. What the writer missed and what the public seems to miss, in my opinion, is this very evident fact. No working unit in any metal industry can match the blast furnace in tons of useful product per unit of time. Talk of substitution is a waste of breath. Studies concerning replacement of iron with other substances within the span of our lives is a waste of time and substance.

What we need, rather, in this country is to provide the transportation facilities to move the ore we know is available. We need some reasonable assurance that coal will be mined to provide the required coke. (The nearly 30,000,000 tons of steel lost during strike periods in the last five years has been a more important cause of deficit than lack of expansion.) We need the communities, now thriving because of steel plants, to recognize that the coke oven and blast furnace are industry's economic guarantee of their future.

A tax system that does not provide for replacement of worn-out equipment could wreck our plants as effectively as bombing. A tax system that works against the development of iron ore reserves has our key munitions industry always in doubt as to what the real ore situation will be in times of stress.

To the people of this audience it is my earnest plea that the real story be told. We are all in this boat together, and while the blast furnace crew may be only the "black gang" on this boat, they too are important.

To my friends among blast furnace men I wish to convey my humble appreciation for the hours they have spent to open my eyes to their problems. To my present associates, the operating group of Republic Steel, I wish to give credit. To Joe Slater, Frank Janacek, now gone, Walter Montgomery, Robert Liggett, Don Babcock, Walter Carroll, John Hazel, M. Fedock and others, I acknowledge my debt. The A. D. Little Co. men under the direction of Bruce Old who have lived with us are also a part of the group.

A new technique for microscopic observation is described. Conventional metallographic microscopes may be converted to "phase microscopes" by the addition of an annular stop in the illuminating system and a phase disk in the image of the stop.

Phase Contrast Metallography

THE GREATER the variety of conditions under which a metallographic specimen can be observed, the more information can be gained concerning it. The metallurgical microscope has been developed over the years until it has become a complex and versatile instrument. The more elaborate microscopes are equipped so that the operator may conveniently control various techniques of illumination and thus gain as much information as possible about the characteristics of the specimen. Up to the present time there have been three principal observation techniques offered: bright field, dark field, and polarized light. This article will describe an accessory which adds another technique, that of phase contrast observation, to current metallographic microscopes.

It is undoubtedly true that by far the greater part of the work done with the metallurgical microscope has been with central axial bright field illumination with full or slightly reduced aperture. Under such conditions, a properly polished and etched specimen is seen as being composed of crystals or grains. The grain boundaries generally appear as dark lines and the individual grains are lighter or darker than their neighbors according to their absorbing and scattering characteristics. Variations of bright field illumination that are of value for securing a relief impression of the specimen surface are obtained by the use of conical or half-aperture illumination or by using a decentered aperture diaphragm.

Dark field illumination produces images of high contrast and high resolving power. This technique is useful in studying surface conditions, as minute scratches and pits are made quite evident. It is also of value, although somewhat limited, in the identification of inclusions in steel.

Polarized light microscopy is finding wide favor as an aid in the identification of the constituents of alloys, in revealing the structural phases in steel, and in the investigation of grain size. Measuring accessories for use with polarized light[1, 2] permit quantitative measurement of the ellipticity and rotation of the polarization produced by the object. Also, very weak anisotropy is made visible with these devices.

In addition to bright field, dark field, and polarized light, we have recently developed an accessory permitting phase contrast observations to be made on current models of metallographic microscopes. Since the demonstration of this accessory at the Metal Show in October 1949, there has been considerable interest shown in the possibilities of phase contrast in metallography, and a technical description of it and what it can be expected to accomplish would seem timely.

The principles of phase contrast microscopy were first applied to the biological microscope in order to render visible, without staining, objects which are highly transparent. It is beyond the purpose and scope of this paper to go into the basic theory of the phase contrast microscope, a subject which has been adequately covered elsewhere.[3, 4] It will suffice here to say that if an opaque specimen has elevated or depressed areas in its surface, normal methods of observation will show no more than the boundaries separating these areas, whereas the phase method of observation will render different heights visible as different shades of gray.

A normal bright field microscope is converted to a phase microscope by two additions:

[1]References are on p. 727.

By R. L. Seidenberg and J. R. Benford
Scientific Bureau
Bausch & Lomb Optical Co.
Rochester, N. Y.

1. The illuminating beam is restricted to a hollow cone of light by simply inserting a transparent annulus in the illuminating system.

2. A phase-retarding annulus is located in the image of the transparent annulus after the light has been diffracted by the specimen.

This diffraction by the specimen is of a different nature than ordinary diffraction. Ordinary diffraction is caused by varying degrees of brightness in the specimen, whereas the diffraction which we are concerned with is caused by varying degrees of phase in the specimen. In transmitted light the varying degrees of phase may originate

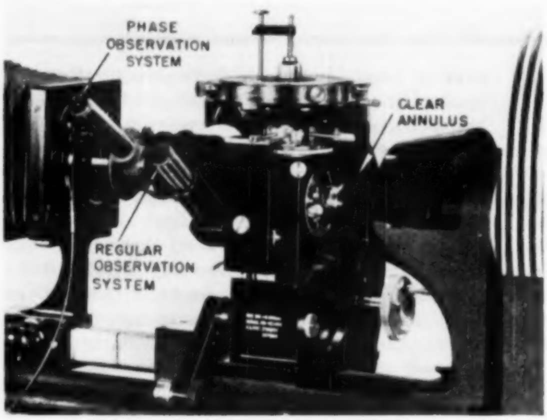


Fig. 1 — Phase Contrast Accessories Attached to a Current-Model Microscope

from varying refractive index or varying thickness. In reflected light these differences in phase may come from varying surface elevation or varying specimen composition.

In the biological phase contrast microscope, the transparent annulus and the phase-retarding annulus, mentioned above, are located in the front focal plane of the condenser and the rear focal plane of the objective, respectively. It would seem, at first glance, that there would be no problem in adapting such a system to the microscope employing vertical incident illumination. There are, however, two serious complications which arise when a phase-retarding annulus is incorporated into a metallographic objective. The phase pattern is, in practice, made of two evaporated films. One film serves to retard in phase all light rays passing through it. The other film is an absorbing material and acts to reduce the intensity of the rays which are specularly reflected from the specimen. With vertical illumination this absorbing material reflects a substantial portion of the incident light directly back to the eyepiece, casting a haze over the image. Secondly, the light has to pass through this absorbing material twice, resulting in a very large loss of light.

One solution of the foregoing difficulties is to locate the phase-altering annulus on the eyepiece side of the vertical illuminator.[5, 6] In this location only the image-forming rays pass through it and no harmful reflections or light losses are produced. Such an adaptation, however, poses serious mechanical problems and would very likely mean that the purchase of a new microscope would be required of the metallurgist.

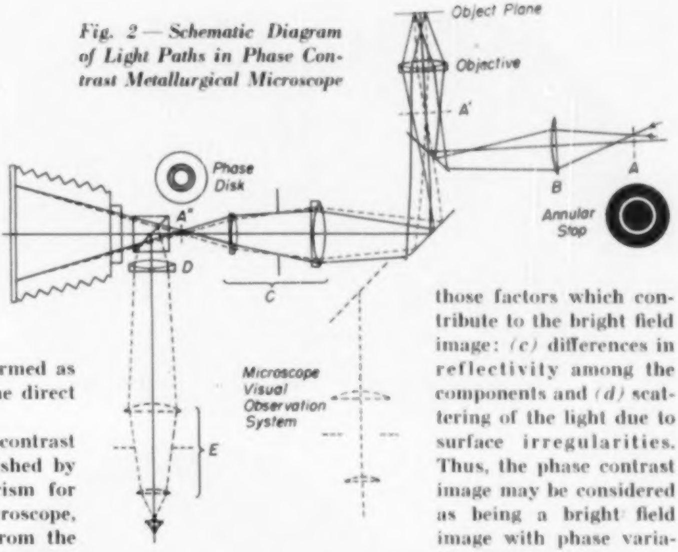
The phase contrast system which is about to be described was designed for the purpose of providing an accessory unit for any of three current model inverted metallographic microscopes. Figure 1 shows the accessory in place on one of these microscopes. The unique feature of the system is that no special objectives or objective-illuminator units are required; all of the standard metallographic objectives as ordinarily used on these microscopes may be used. This is made possible by locating the phase annulus in an *image* of the objective aperture rather than in the aperture itself. To accomplish this a special lens system (C in Fig. 2) was designed to go in the position normally occupied by the camera eyepiece. This lens system performs the function of the camera eyepiece, but in addition is so designed as to form a well-defined image of the objective aperture, a condition which the normal camera eyepiece does not meet.

Figure 2 shows schematically the optical system of the phase unit in combination with the microscope. As is customary when employing Kohler illumination, the light source is imaged by a lamp condenser (not shown) at A, the plane of the aperture diaphragm. An annular stop, as indicated, is located at A. The condenser lens B images this stop at A', the rear focal plane of the objective. The objective forms an image of A' at infinity and, after reflection by the specimen, the annular stop image is re-imaged upon itself at A'. The special projection lens system C images A' at A'' and at this point the phase-altering annulus is located. A beam-splitting cube allows the greater part of the light to pass on out to the camera and directs the remaining light to the phase visual observation system.

Lens D converges the light and brings it to a focus for use with any standard eyepiece, E. The light rays drawn with a solid line are representative of the direct illuminating rays which are specularly reflected by the specimen; the dotted

rays represent light which is "phase diffracted" by the specimen structure, hence is out of phase with the direct or undiffracted light energy. It will be seen that at A'' the direct rays pass through the phase-altering region of the phase pattern while the diffracted rays pass through the clear glass portion of the phase disk. It is at this point that the diffracted rays are effectively retarded in phase by one quarter of a wave length of green light. The final phase image is formed as a result of interference between the direct and diffracted rays.

Fig. 2 — Schematic Diagram of Light Paths in Phase Contrast Metallurgical Microscope



The switch-over from phase contrast to normal bright field is accomplished by simply inserting the reflecting prism for the normal visual tube of the microscope, and removing the annular stop from the illumination system. If the annular stop is left in place, observation will be under bright field conical illumination. For preliminary survey work the stop can generally be left in place, and the observer can quickly convert back and forth between phase and conical observation to determine whether phase contrast is adding to his knowledge of the specimen structure.

Photomicrography is carried out in the usual manner with the exception that once the light is directed for phase contrast use, no further redirection of the light is necessary for photography. A light-tight adapter is integral with the housing of the phase contrast unit. The manner in which to interpret properly the phase contrast image of an opaque specimen is rather complex. The pure phase contrast effects result from *(a)* irregularities in the surface level of the specimen, brought about by the polishing method or by the preferential attack of the etchant and *(b)* differences in the phase shift on reflection from the different constituents of the specimen. To these must be added those factors which contribute to the bright field image: *(c)* differences in reflectivity among the components and *(d)* scattering of the light due to surface irregularities. Thus, the phase contrast image may be considered as being a bright field image with phase variations made visible.

The unit has been designed to give positive, or dark, contrast; that is, regions of greater optical path in the specimen will appear darker than regions of shorter optical path. Thus, if a homogeneous specimen is under examination, light areas in the phase contrast image will indicate an elevated area in the specimen. Depressions, such as pits and grooves, will appear dark. Because phase contrast does make minute surface irregularities visible it should prove to be of value in the study of surface finishes.

In the study of nonhomogeneous specimens, the interpretation of the phase image becomes more complex, as phase shifts upon reflection from the various constituents will be made evident. F. W. Cuckow[7] suggests that a thin film of aluminum be evaporated on the surface of the specimen in order that these differential phase shifts be eliminated on reflection. The image of a specimen so prepared would be influenced solely by variations of surface level, elevated areas appearing lighter

References

1. "Optische Messmethoden in Polarisierten Auflicht", by M. Berek, *Fortschritte der Mineralogie, Kristallographie und Petrographie*, V. 22, No. 1, 1937.

2. "A Polarized Light Compensator for Opaque Minerals", by A. F. Turner, J. R. Benford and W. J. McLean, *Economic Geology*, V. 40, January-February 1945, p. 18.

3. "Phase Microscopy", by A. H. Bennett, H. Jupnik, H. Osterberg and O. W. Richards, *Transactions*, American Microscopical Society, V. 65, April 1946, p. 99.

4. "Das Phasenkontrastverfahren und seine Anwendung in der Mikroskopie", by A. Kohler and W. Loos, *Naturwissenschaften*, V. 29, 1941, p. 49. (Translation in *Textile Research Journal*, V. 17, February 1947, p. 82.)

5. "Phase Microscopy With Vertical Illumination", by H. Jupnik, H. Osterberg and G. E. Pride, *Journal of the Optical Society of America*, V. 38, April 1948, p. 338.

6. "The Phase-Contrast Microscope With Particular Reference to Vertical Incident Illumination", by E. W. Taylor, *Journal of the Royal Microscopical Society*, V. 69, May 1949, p. 49.

7. "The Phase Contrast Incident Light Microscope", by F. W. Cuckow, Iron and Steel Institute Papers, January 1949.

than depressions. Such a method, however, would preclude the possibility of identifying constituents that would otherwise be recognizable.

Comparison Micrographs

Figure 3 shows comparison micrographs taken in bright field and phase contrast. Each bright field picture was taken using central axial illumination at approximately ⅔ aperture. The pearlite lamellae and the carbide particles in the pearlitic and stainless steels, respectively, appear as a light shade of gray in the phase contrast pictures, indicating that these constituents are elevated above the general surface level of the rest of the specimen.

The phase contrast image of the monel sample provides excellent contrast between the various crystals in comparison with the bright field image, and adds information about the relative surface levels of adjoining crystals. As one passes a depression-elevation boundary, the light shades off in the depressed side and brightens up in the elevated side.

As more metallographers adopt the use of the phase contrast method, many interesting and valuable applications will undoubtedly be disclosed. A new and relatively unexplored field of research is offered to the metallurgist, and from this research may be expected further contributions to metal science.

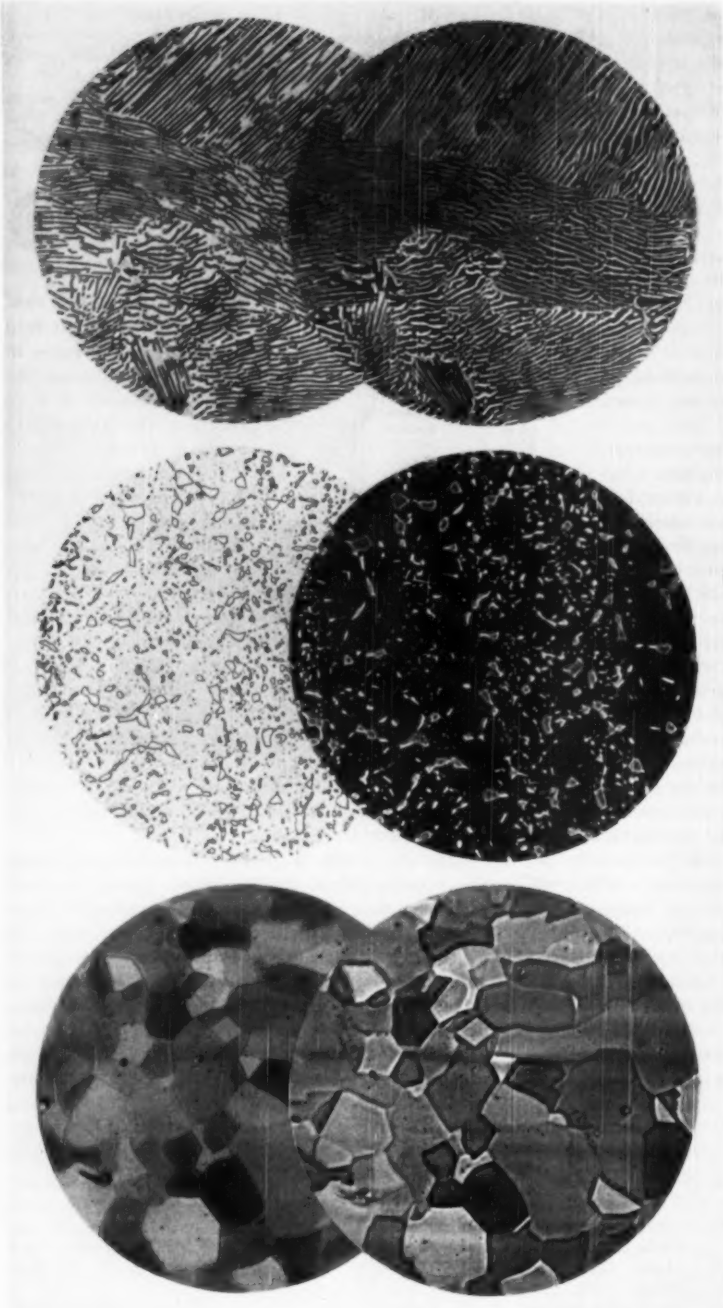


Fig. 3—Comparison Micrographs. Bright field (left) and phase contrast (right). Pearlite at top, stainless steel at center, monel metal at bottom

Difficulties now existing in the foundry production of nodular iron (malleable, as-cast), due to necessary close control of inoculant and variation of properties with section size, may be removed by metallurgical improvements, such as desulphurization in basic cupolas by calcium carbide flux.

Nodular Iron; Theory and Practice

A CONFERENCE in mid-September, arranged by Howard F. Taylor of the department of metallurgy, Massachusetts Institute of Technology, attracted an international group of metallurgists and foundrymen who have been most concerned with the nurturing of this lusty infant of the foundry metals. It is only logical and proper that the scientific fundamentals be considered as the first item on the agenda, and consequently Alfred Boyles of the United States Pipe & Foundry Co. opened with a discussion of the mechanism of formation of flake graphite in ordinary cast iron, using the arguments set forth in his book on "The Structure of Cast Iron", published by the ⊕. Very, very briefly, the situation is this:

In a normal hypo-eutectic iron, austenite dendrites crystallize from the melt until the remaining liquid is of eutectic composition. Freezing of the eutectic then begins at crystallization centers independent of the previously solidified dendrites. At these crystallization centers flake graphite and solid gamma iron form together. Inoculation increases the number of eutectic crystallization centers to give smaller cells and the normal Type A graphite.

The opening salvo on the mechanism of formation of spherulitic graphite in cast iron was fired by H. Morrogh of the British Cast Iron Research Association (whose 1948 papers first introduced nodular iron to most American metallurgists). He pointed out that whereas graphite *crystals* consist of widely spaced hexagonal sheets, strongly anisotropic and with the basal plane of the hexagon parallel to the sheets, a graphite *spherulite* consists of an aggregate of crystallites radiating from a common nucleus, and the basal plane of each such crystallite is normal to the radius of the spherulite. (Perhaps it is an evidence of the present state of knowledge that even this last statement is somewhat controversial. Some X-ray diffraction evidence was presented by Dr. Larsen of Dow Chemical Co. that graphite in spherulites may be rhombohedral with layers in ABC-ABC pattern instead of the usual hexagonal AB-AB pattern.)

Methods of Treatment — Mr. Morrogh stated that graphite spherulites could be produced in nine or ten different ways and that any theory as to the mechanism must find the common thread for all methods. Among the methods of producing graphite spherulites are the following: In the solid phase by annealing white-heart malleable castings high in sulphur and low in manganese; in as-cast cobalt-carbon and nickel-carbon alloys by treatment of the melt with either Ce, Ca, Mg, Zn, Cd, Bi (or in low-sulphur melts simply by rapid cooling); in hypereutectic irons by treatment with cerium; in hypo-eutectic or hypereutectic irons by treatment with magnesium. The two last methods are of some commercial importance and are patented.

Examples were also shown of good quality nodular graphite cast iron produced by treatment with calcium. Some spherulites were formed during freezing in a cast iron with very high sulphur, low manganese. In tellurium-treated irons, spherulites are often found just behind the chill. Bismuth was also found to be effective in causing some spherulites to form in cast iron during freezing. In pure iron-carbon alloys, merely rapid cool-

By *Metal Progress's* Special Representative

ing produced some spherulites. R. A. Flinn of the American Brake Shoe Co. added the interesting information that nodular graphite had been produced in thin castings by treating the molten metal with boron carbide, titanium carbide, and calcium carbide plus a magnesium salt.

A comparison of the magnesium and cerium treatments led to the conclusion that there may be no fundamental difference except that more cerium may be required to produce a given effect because of its higher atomic weight.

Theories for the formation of graphite spherulites involving nucleation and undercooling were discussed. Morrogh inclines to the view that extraneous nuclei (other than graphite) are not required, and that the spots observed microscopically in the center of spherulites are optical effects caused by the plane of polishing coinciding exactly with the basal plane of a radial crystallite. This view is not universal. For example, Professor De Sy presented evidence (in *Metal Progress* for June 1950) gained with electron microscope that a nongraphitic nucleus does exist, and chemical evidence that it is a magnesium compound in a magnesium-treated iron.

Furthermore, J. E. Rehder of the Bureau of Mines, Ottawa, Canada, described some studies on the nucleus. Evidence of both light and electron micrographs indicates that there is nuclear material other than graphite in the centers of the nodules. The nuclei appeared to be harder than the graphite composing the remainder of the nodule. Nodules from a magnesium-treated iron were separated by dissolving away the iron in weak acid and further separating other nonmetallic inclusions by heavy liquid flotation. Measurement of over 1000 nodules gave an average diameter of about 50 microns with a distribution of sizes between 10 and 90 microns. Several samples of separated nodules were burned to remove the carbon and the ash analyzed. The MgO content of several samples of the ash showed only 1 to 4%. There was 30 to 50% Fe_2O_3 in the ash, some SiO_2, and (surprisingly) TiO_2 in the order of 30 to 40%. No definite conclusions were drawn but Mr. Rehder indicated that nodules do form on specific (presumably nongraphitic) nuclei.

Foundry Production and Commercial Applications

Two schools of thought exist as to the commercial importance of nodular iron — one optimistic, the other much less so. Naturally enough, the optimistic view was taken by A. P. Gagnebin of International Nickel Co. in his discussion of "The Status of Ductile Iron in American Industry". He pointed out that ductile iron (or nodular graphite iron), produced by magnesium treatment, is not a single material but a family of materials in which the matrix may be ferritic, pearlitic, martensitic, or austenitic — with properties varying according to the matrix structure. About 3500 tons of these various irons were produced last year and between 15,000 and 20,000 tons are expected to be produced this year. Properties obtainable in the various irons were reviewed and proposed specifications discussed. Examples of present commercial uses include compressor bodies, cylinders and pistons, rolls, axle housings, anvil blocks, gears, crankshafts, and plowpoints. According to Mr. Gagnebin, the useful combination of properties — the process advantages of cast iron with the product advantages of both iron and steel — will eventually place ductile iron third in tonnage among ferrous metals, immediately behind rolled steel and gray cast iron and ahead of malleable iron and cast steel. Truly a bright future!

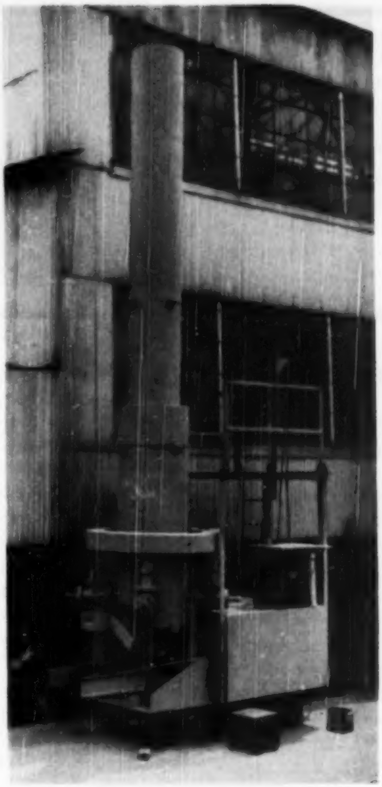
A considerably less hopeful view was taken by Harold Bogart of Ford Motor Co. who reviewed the subject from the large-tonnage automotive foundryman's standpoint. Extensive test data were shown for two basic irons, correlating the effect of section size and of varying magnesium contents on the mechanical properties of the castings. Effects of heat treatments were also shown. Mr. Bogart pointed out that optimum properties are obtained only within a narrow range of magnesium content — around 0.04 to 0.05% — a range which is exceedingly difficult to maintain in production. Properties of heavy section castings are considerably poorer, and increasing the magnesium does not improve them. Other problems mentioned were the gating and feeding of castings to prevent shrinkage and the marked segregation sometimes encountered. All in all, he felt that nodular iron may not become the widely used material of commerce that Mr. Gagnebin predicted.

Some, at least, of the present hurdles may be jumped by improvements in foundry metallurgy, either known at present or to be perfected in the future. For example, the efficiency of magnesium or cerium additions to produce nodular iron seems to be dependent primarily on the sulphur content of the base iron. With low-sulphur iron the nodulizing alloy addition may be one third that required for an ordinary cupola iron. The problem is to get low-sulphur iron from the coke, pig iron and scrap now available by some method that costs less than the inoculating reagent otherwise required. C. K. Donoho of American Cast Iron Pipe Co. called attention to the achievements of the basic lined cupola in this respect.

When the cupola is lined with magnesite

brick and a basic, reducing slag made with commercial calcium carbide as the flux material, remarkable desulphurization can be accomplished in the cupola. One heat cited averaged 0.009% sulphur. Concomitant results of this basic practice are higher melting temperatures and increased carbon pick-up. It was shown that high-quality, low-sulphur iron can be produced by the basic cupola practice from either 100% cast scrap or 100% steel scrap, and the over-all economics of the process seems to be favorable for commercial production of nodular iron.

John Chipman of Massachusetts Institute of Technology ably outlined the physical chemistry of desulphurization. The role of alumina in basic slags was clarified; although Al_2O_3 acts as an acid in basic slags it is not an oxidizing agent as SiO_2 may be, and consequently does not retard desulphurization as strongly as does SiO_2.



Experimental Cupola, Basic Lined, Capable of Producing 0.006% S Iron (American Cast Iron Pipe Co.)

Genesis of the Nodules

A very interesting interchange of views was had upon the genesis of the graphite spherulites, in the sense of the *time* during the solidification process in which they appear. Mr. Morrogh told of some quenching experiments on cerium-treated hypereutectic irons which indicate that graphite spherulites form in the liquid metal prior to the eutectic arrest. This is also evidenced by flotation of such nodules; they appear to be closer together in the upper parts of heavy sections. In hypo-eutectic irons treated with magnesium the eutectic arrest is smoothed out but the evidence is not clear as to whether the spherulites form in liquid or in solid metal.

In this connection Prof. Albert De Sy of the University of Ghent, Belgium, described current research on "spheroidal" graphite cast iron in his country. Examples were given of cast iron containing graphite spherulites in the as-cast condition, produced by treatment of the molten iron with Ce, Mg, Li, Ca, Ba, Sr, Na, or Te. The last two produced irons which were only partially nodular. In discussing the mechanism of formation of graphite spherulites in cast iron, Prof. De Sy showed some typical cooling curves through the freezing range for several nodular and flake graphite irons. The nodular irons have a much less definite eutectic arrest than do the flake graphite irons. With regard to the question of when nodules are born, he thinks the spherulites may form either in fully liquid metal or in fully solid metal, but never at the solid-liquid interface, where presumably flake graphite forms.

Summary

Although called by almost as many different names as there are speakers on the subject, the production and properties of nodular irons are now generally understood. It is apparent that at least ten different elements can be used to treat molten iron to produce graphite spherulites in the solidified metal. Of these, one group is composed of strongly alkaline desulphurizers, such as magnesium, cerium, lithium and calcium. In an entirely different group are such acid elements as sulphur, selenium, and tellurium. The latter elements are most effective in low-manganese irons.

In hypereutectic iron there is ample evidence that graphite spherulites separate from the wholly liquid phase. In hypo-eutectic irons the evidence is not yet clear. Although all precipitation of a solid phase must be by a process of nucleation and growth, there is yet no precise and acceptable evidence that the microscopically visible nuclei in nodules at high magnifications consist of anything other than graphite.

The conflicting opinions as to the eventual commercial position of this new material relative to the older ferrous foundry metals will be resolved only by time and experience.

Correspondence

Cathodic Vacuum Etching

London, England

Messrs. McCutcheon and Pahl, in their article in *Metal Progress* for November 1949 (p. 674), state that cathodic vacuum etching of metals should be of considerable interest to metallographers. Thus a method which was divulged 25 years ago is at last put into extensive use.

Their literature references note that W. Feitknecht published the first article in Switzerland in 1924, and Cyril Stanley Smith another in England in 1927. This note is to record the fact that the present author contributed a memoir to the Polish Academy of Sciences in 1925 (*Bulletin*, 1925, Series A, p. 81 to 92) on "Cathodic Sputtering of Alloys". The work was done in the physics department of the University of Warsaw under Professor Pienkowski. Sputtered films and the structure on the surface of the sputtered specimen were photographed; the latter gave a very delicate design, quite similar to that obtained by conventional etchants. A variety of alloys were studied including solid solutions such as α Cu-Al, eutectic alloys such as Bi-Cd, and alloys with intermetallic compounds such as Sb-Zn. It is clearly pointed out that the method can distinguish between the polished surfaces of pure metals (solid solutions) and highly dispersed heterogeneous structures.

Józef Mazur
Metallurgy Department
Royal School of Mines

Transfer of Replica From Metal to Electron Microscope

Blawnox, Pa.

Metallographers usually depend on Scotch tape and a specimen screen to remove the Formvar replica from a metallic surface, prior to examining this replica under the electron microscope. As many will attest, this scheme leaves much to be desired; whenever the replica really sticks to the metal, the Scotch tape cannot remove it. We have found that a much better scheme is as follows:

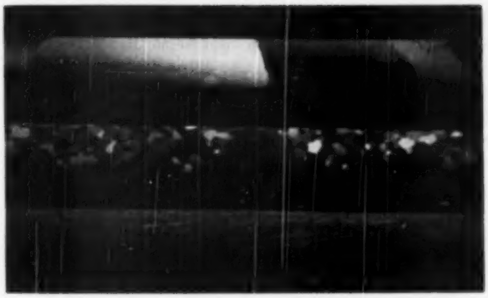
The specimen screen, prior to being placed against the surface of the Scotch tape, is first immersed in a very dilute solvent solution of resinous materials, plasticized so that upon drying a very tacky adhesive ensues. After immersing, the screen is removed from the adhesive solution and the center portion openings of the screen are blown free of the plastic material by an air stream from a micropipette. The air should be dry and of sufficient volume to evaporate the solvent of the mixture. The screen is then placed against the surface of the Scotch tape and the remaining procedure carried out as usual. By this means the screen has been effectively coated with an adhesive film which does not affect its porosity and which effectively adheres to and helps remove the plastic replica and which remains stable within the electron microscope under conditions of vacuum, heat and electron bombardment.

Harold C. O'Brien, Jr.
Director of Research
Royston Laboratories, Inc.

Galvanic Macro-Etch for High-Purity Aluminum

Cambridge, Mass.

In a study of the recrystallization of high-purity aluminum (Cu 0.002%, Fe 0.03%, Si 0.06%, Mn 0.001%, Mg <0.001%), a very simple macro-etching technique was used to prepare the samples, which were polished before heat treatment with 000 emery paper coated with paraffin. The recrystallized aluminum bars were dipped for about three quarters of their length into a 15% solution of HCl and externally coupled with an 18-8 stain-



Recrystallized Aluminum Rods Etched by Galvanic Action. Enlarged 1.2 diameters

less steel rod dipped into the same solution. After a suitable time, the aluminum bars were removed, rinsed in water, rinsed in alcohol or acetone, and dried. This was then repeated after reversing the position of the bar to etch the unetched top portion. In doing so the center of the bar was doubly attacked, but this is desirable since the portion is etched more slowly near the surface of the electrolyte.

The galvanic action due to coupling with a more noble electrode increases the etching rate and gives a better contrast to the final structure. The galvanic action is stronger the larger the ratio of the cathodic (stainless steel) to anodic (aluminum) surface immersed in the electrolyte.

The electrolyte concentration and other conditions are not at all critical. The acid concentration and the ratio of cathodic-to-anodic areas should be adjusted in order to obtain a good etch in about 5 min. If the rate of attack is too fast, the metallographic structure appears uneven and sometimes stained. On the other hand if the rate of attack is approximately right, longer times of treatment do not give undesirable overetching within very broad limits of time. As a rule, the coarser the grain size, the milder the condition of attack should be.

This galvanic etching is also suitable for revealing the macrostructure of aluminum of higher purity. It was not satisfactory for annealed 2S aluminum; whether this is due to the associated alloying elements in commercial aluminum or to the structure of our sample is unknown.

A note on our method of making the large crystals may be of interest. Several $\frac{3}{8}$-in. rods as-received were machined to 0.30-in. diameter. The lower rod in the illustration (grain size 0.05 to 1.3 mm.) was annealed 30 min. at 700 to 775° F. The middle one (grain size 3.5 mm.) was annealed 13 hr. at 1150° F., stretched 3 to 4% and re-annealed 17 hr. at 1150° F. The top one (monocrystal 1½ in. long) had the following history: Anneal 30 min. at 1100 to 1150° F.; cool; bend 1½ in. from each end; straighten by hand; re-anneal at 1100 to 1150° F. overnight.

I. S. Servi
Research Assistant
Metallurgy Department
Mass. Institute of Technology

Hallowe'en

Philadelphia, Pa.

When the frost is on the pumpkin, hob-goblins stalk the land. They even get into ball bearings!

The light pattern in the large steel ball (made of S.A.E. 52100) is a low-carbon steel inclusion and the photograph is exactly as the ball appeared after hardness testing and then etching in hot 50% hydrochloric acid.

The low-carbon inclusion resulted from the steel plate, which is normally attached to the top of the ingot mold plug, breaking away and floating up into the molten steel. This plate is used to prevent impingement of the molten steel directly on the plug, which might result in fragments of the plug getting into the steel. After rolling and drawing into ball wire and pressing into balls, the plate took the form shown in the photograph of the round ball.

H. O. Walp
Chief Metallurgist
S.K.F. Industries, Inc.

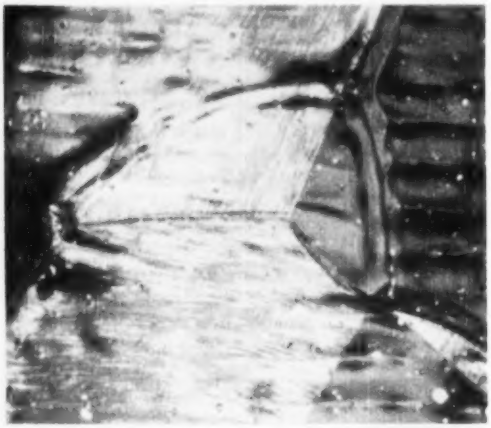
Thermal Polishing and Etching

London, England

We are interested to read the letter from Glen W. Wensch (*Metal Progress*, April 1950, p. 488) describing phenomena observed on the surface of nickel specimens after long times of annealing in sealed evacuated tubes. Under these conditions a considerable redeposition of nickel on the specimen from the vapor phase would be

expected, and this may well contribute to the polishing effect observed. However, we believe that surface migration is a more potent mechanism: this will act in such a way that the free energy of the surface is reduced, as will occur if the surface area is diminished by the removal of scratches and other irregularities.

Although Mr. Wensch does not refer to any investigation of these processes earlier than 1941, R. Shuttleworth (*Metallurgia*, Vol. 38, 1948, p. 125) in a review of the subject gives 1910 as the date of the first observation of thermal etching (W. Rosenhain and J. C. W. Humfrey, *Proceedings* of the Royal Society, Vol. A83, 1910, p. 200). The earliest date at which thermal polishing was noticed appears to be 1938 (R. P. Johnson, *Physical Review*, Vol. 54, 1938, p. 459), although three years previously E. N. da C. Andrade and J. G. Martindale (*Philosophical Transactions* of the Royal Society, Vol. A235, 1935, p. 69) had shown that surface migration could take place at 280° C. on silver. In view of Mr. Wensch's last paragraph he will no doubt be interested to read the paper by M. J. Day and J. B. Austin (A.S.M. *Transactions*, Vol. 28, 1940, p. 354) on the determination of austenite grain size by this technique.



Equilibrium Surface of Nickel Rod (75×) Heated Under Slight Compression in Vacuum to 1410° C., Showing Effects of Viscous Flow and Grain Growth

In the laboratories at the University of Cambridge we are using this technique to examine metals at elevated temperatures, using a reflecting microscope. While we find that the equilibrium surface is rarely as smooth as a mechanically polished surface, the irregularities are of interest in themselves, being related to the internal structure of the metal. We can confirm Mr. Wensch's observations on nickel and the accompanying photograph shows some additional interesting features. The photograph (magnification of 75×) was taken using plane-polarized light, and is of a 99.9% nickel dilatometer specimen of ⅜-in. diameter. This has been slowly heated to 1410° C. (2570° F.) in vacuum under a small load, and it can be seen that the original machining grooves have been rounded and reduced in depth. Under the load, creep has occurred (about 1% compression), principally of the "viscous flow" type in the grain boundaries, as is shown by the ridges formed by the metal which has been squeezed out. The furrow along the top of each ridge shows the original location of the grain boundaries as revealed by thermal etching. Subsequent grain growth has eliminated a small grain originally at the center of the field and larger polyhedral grains have been formed with boundaries meeting at about the equilibrium angle of 120°. During this recrystallization and growth, twinning has also occurred, shown by the development of texture on the surface of the specimen.

We concur with Mr. Wensch that the phenomenon is of intrinsic interest and is undoubtedly proving to be a valuable extension to available metallographic methods.

A. G. Metcalfe and M. J. Olney
Department of Metallurgy
University of Cambridge

Circular Graphite in Cast Iron

Birmingham, England

The letter published in the April issue of *Metal Progress* from C. K. Donoho is interesting, but I can only believe that the term "exclusive development" refers to the words used, namely, "circular graphite", and not to the structure itself. This structure has been produced and described in the literature previously. For instance, the structure was produced by Morrogh in high-sulphur cast irons and illustrated in the *Journal* of the Iron and Steel Institute, No. 2, for 1946, Fig. 13 to 17, although the term "circular graphite" was not used. The structure was also referred to by Morrogh and Williams in the *Journal* of the Iron and Steel Institute for March 1947. In these references the term "mesh" or "mesh-like" graphite has been used. More recent references to this type of structure have appeared in the *Journal of Research and Development* of the British Cast Iron Research Association for February 1950, and also some perfect illustrations have been given still

more recently by Williams in the April 1950 issue of the *Journal* of the Iron and Steel Institute.

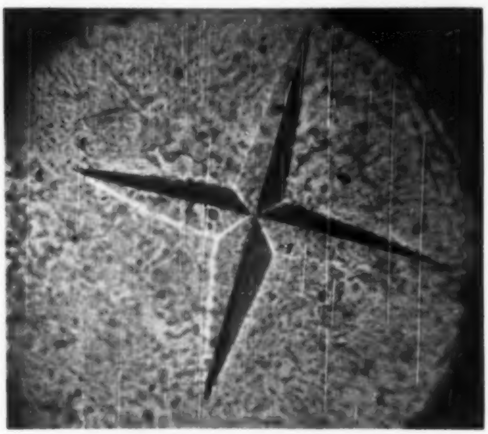
Mr. Donoho suggests that further work will be directed to "how to make it again". The answer to this will be found in the above references. I can only say that I am in sympathy with him when he says "what to use it for and why make it at all."

H. MORROGH
Research Manager
British Cast Iron Research Assoc.

Star Fish or Compass-Rose?

LONDON, ENGLAND

Being a quadruped it cannot be a star-fish! Likewise, the attractive compass-rose is not taken from an old chart, but is the result of two indentations with a double-conical diamond indenter on a specimen of cast tin. Crossing of indentations is not a technique to be recommended; possibly when it occurs accidentally it ought not even then be published. Nevertheless, readers may be interested to note that the first indentation is practically of the same length as the second one, thus revealing no work hardening. In the present case the "Double Cone" hardness is $H_{dc} = 21$ kg. per sq.mm. The measured Vickers hardness (diamond pyramid) is DPH = 18 kg. per sq.mm. Applied load was 50 g., the magnification 400×. The advantage of the Double Cone indenter is the elongated impression similar to that obtained with the Knoop indenter.

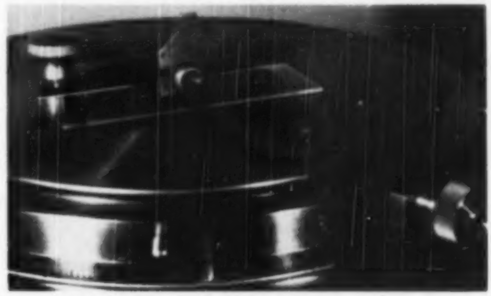


W. STERN
Diamond Research Department
Industrial Distributors (Sales) Ltd.

Quick Estimation of Case Depth

BLOOMFIELD, N. J.

In the production of small parts we frequently desire to check each batch for case depth as it comes from the Homo-Carb furnace; therefore we do not want to take the time required to mount them in bakelite. The sample (in the illustration it is a float arm, about ½ x ½ in., punched from 0.035-in. mild steel) is ground on a fine-grit grinding wheel, followed by a few strokes on No. 00-grit emery paper. This surface is smooth enough to bring out the case with a 2% nital etch. Then the sample is placed on a glass microscope slide and is held erect by small pieces of modeling clay. When the slide is placed on an inverted-type microscope and viewed with polarized light, the case is easily measured with a micrometer eyepiece. (With the usual bright-field illumination, reflected light is deflected by the glass slide and it is impossible to see the sample.)



Thin Sample Held to Microscope Slide by Plastic Clay; Polarized Light Avoids Reflections From Surface of Glass Slide

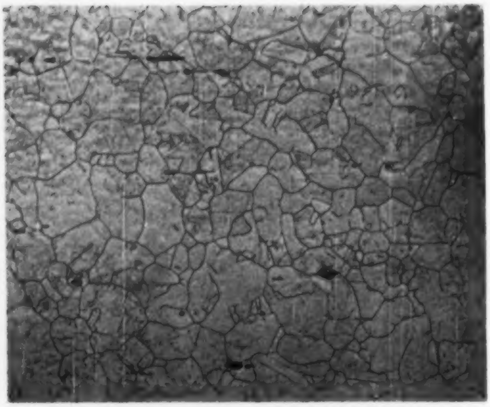
If it is necessary to see the grain size or to get a rough estimate of structure, the sample can be given the usual polishing and etching steps following the grinding, and the polarized light will outline the grain boundaries.

MARIE H. WHITEHILL
Metallographer
Air Conditioning Department
General Electric Co.

Electrolytic Polishing of Nickel

LOS ALAMOS, NEW MEXICO

Since manual polishing, followed by chemical etching of nickel, is a time-consuming process, often producing an inferior surface due to surface distortion and the lack of strong preferential



Nickel, Annealed at 800° C. (1475° F.) for 25 Min., Electropolished and Electro-Etched

chemical action demonstrated by most etchants toward nickel, a rapid method of surface preparation was sought in a recent investigation of recrystallization of plastically deformed nickel. Various existing procedures of electropolishing nickel were evaluated, and the most promising method was that of Hothersall and Hammond ("The Anodic Polishing of Electrodeposited Nickel", *Journal* of the Electrodepositors' Technical Society, Vol. 16, 1940, p. 83).

However, experience indicated that this should be modified for best results to the following:

Solution	:	390 cc. concentrated sulphuric acid plus 290 cc. distilled H_2O.
Cathode	:	Nickel
C.D.	:	39 amperes per square decimeter
Time	:	4 to 6 min.
Temperature	:	95° F. maximum

In some instances the electropolished surface had such high reflectance that difficulty was encountered in focusing the microscope! The solution described above did not etch when used at lower current densities.

An investigation of many common reagents revealed that the nickel so polished could be beautifully electro-etched according to the following formula:

Solution	:	53 cc. 85% orthophosphoric acid to 100 cc. distilled H_2O.
C.D.	:	1.55 amperes per square decimeter
Time	:	1 to 4 min.

The accompanying figure clearly shows the excellence of this method.

GLEN W. WENSCH
Los Alamos Scientific Laboratory

NOTE: These investigations were carried out while the author was at the University of Illinois.

Permanent Record of Magnaflux Indications

COLUMBUS, IND.

Frequently it is necessary, for record purposes, to make Scotch-tape prints of defects found by the magnetic-particle inspection method. The procedure commonly used is to obtain the particle pattern of the defect in the normal manner from a suspension of the black paste in Stoddard's solvent. Then you have a choice of allowing the solvent to drain off for several hours, or (preferably) let the sample drain overnight in a dust-free room. Or, you may flow carbon tetrachloride cautiously over the pattern, hoping it will not wash partly away.

The writer has found a quick way of preparing the sample so a tape print can be made in a few minutes, by using a 1½% (by volume) suspension of the black paste in carbon tetrachloride. Clean off all oil or grease from the area where the defect is located, or degrease with any of the usual quick drying solvents. Then, while the magnetizing "shot" is put through the part, flow on the powder suspension in carbon tetrachloride. In about a minute the solvent evaporates and the print can be made.

The gray background that appears on such a print, due to scattered magnetic particles which did not drain off, is no worse than that obtained by the old method. We also find that prints of very fine, subsurface indications can be obtained with the suspension in CCl_4 which could not be obtained before.

HAROLD H. LURIE
Chief Metallurgist
Cummins Engine Co., Inc.

Personal Mention

Othmar H. Ammann

A 25-year-old Swiss, just graduated in civil engineering, came to America in 1904 and got a job with the Pennsylvania Steel Co. Immediately he found himself working on minor problems connected with the production of nickel steel eyebars for the Queensborough Bridge in New York City, and here began **Othmar H. Ammann's** life-long career in big bridges. From 1909 to 1912 he was associated with the consulting engineers who investigated the tragic failure of the world's largest cantilever bridge across the St. Lawrence at Quebec. From 1912 to 1925 he was associated with Gustav Lindenthal; as assistant chief engineer of the New York Connecting Railroad, he was in charge of the construction of the Hell Gate Bridge across the East River in New York, at the time the longest arch in existence.

From 1925 to 1939 Mr. Ammann occupied successively the positions of bridge engineer, chief engineer and director of engineering of the Port of New York Authority, and from 1934 also that of chief engineer of the Triborough Bridge Authority. In these capacities he directed the engineering and execution of such major projects as the George Washington Bridge, the Bayonne Bridge across the Kill van Kull, the Triborough and Bronx-Whitestone bridges across the East River with their extensive approaches.

In all of these he has made extensive use of alloy steels, and thus amply warrants the A.S.M.'s Distinguished Service Award "for extensive application of the strong structural steels for long-span highway bridges". The George Washington suspension bridge built by the Port of New York Authority, which with its span of 3500 ft. far surpassed previous structures of its kind, contains 32,000 tons of silicon steel. Othmar Ammann is not bound by convention, for in the Bayonne Bridge, the longest existing arch, he used high-strength manganese steel for the first time in bridge history, being convinced of its advantages in competition with other structural alloy steels for the exceptionally heavy compression members composing the arch ribs.

Gordon Johnson, past-chairman of the North West Chapter of the American Society for Metals, has joined Armour Research Foundation as supervisor of foundry process research. He was previously chief metallurgist of the American Hoist & Derrick Co., St. Paul, Minn.

J. L. Wyatt ⊕ is attending Massachusetts Institute of Technology for graduate study. He was formerly employed by the Titanium Div. of National Lead Co. and the company is sponsoring his research work.

W. Wallace Brenneman ⊕ is now metallurgist for the Crawford Steel Foundry Co., Bucyrus, Ohio.

F. C. Albers ⊕ has been transferred by Chicago Pneumatic Tool Co. from the Detroit manufacturing facilities to the new plant at Utica, N. Y. At the same time he has been promoted to chief metallurgist.

George W. Hastings ⊕, formerly president of Milford Metal Treating Co., Inc., has established a heat treating plant in Benton Harbor, Mich., known as Harbor Metal Treating Co.

James Miller ⊕, who was formerly with the Cornell Aeronautical Laboratory, Buffalo, N. Y., has recently joined the Thomson Laboratory of the General Electric River Works, West Lynn, Mass., as a metallurgist.

H. A. Cavanagh ⊕ is now a sales-service engineer in the Chicago area for Crucible Steel Co. of America.

Edward H. Burrs ⊕ has been transferred by Crucible Steel Co. from the Cincinnati office to the newly established Dayton, Ohio, office.

Climax Molybdenum Co. of Michigan announces the appointment of **Walter F. Craig, Jr.**, ⊕ as metallurgical engineer in the Chicago office. He was previously supervisor of ferrous metals research at Armour Research Foundation.

The Midvale Co., Philadelphia, announces that **A. R. Gaus** ⊕ has been named assistant to the vice-president in charge of sales. Mr. Gaus had represented the Midvale Co. in the Pittsburgh office since 1937.

Roll Manufacturers Institute, Pittsburgh, announces that **Joseph J. Marsalka** ⊕, for the past five years research laboratory supervisor of Blaw-Knox Co., has been appointed technical director of the institute.

D. S. Chambers ⊕ has joined Vanadium-Alloys Steel Co., Latrobe, Pa., and is on the research and development staff of the metallurgical department.

A. A. Bradd ⊕, formerly assistant superintendent of research and of heat treatment for the Midvale Co., is now supervisor of heat treatment for the Philadelphia Gear Works.

After receiving his M.S. degree from Michigan College of Mining and Technology in August, **Earl C. Sutherland** ⊕ has been appointed a technical engineer with the International Business Machines Corp., Endicott, N. Y.

George F. Burditt ⊕ has been transferred by Wheelabrator & Equipment Corp. to Greensboro, N. C., to open a new sales office for the areas of North Carolina, South Carolina, Virginia, West Virginia and northeastern Georgia.

After graduating from the University of Washington in June, **William K. Gibb** ⊕ has joined Boston Electro Steel Foundry as an inspector of castings.

Francis W. Shepherd ⊕, who recently completed the requirements for the degree of master of science in mechanical engineering at the University of Minnesota, has accepted a position as mechanical engineer at the U. S. Naval Proving Ground at Dahlgren, Va., in the experimental department.

Vernon H. Jones ⊕ has been appointed assistant metallurgist in the foundry of the Canadian Westinghouse Co., Ltd., Hamilton, Ont.

Frank V. Bednarczyk, Jr., ⊕, who graduated from the University of Detroit in June, has been employed at Hewitt Metals Corp., Detroit, as plant engineer.

Personals

R. W. Sandelin has been appointed head of the metallurgical department of Connors Steel Co., Birmingham, Ala.

E. E. Staples has been promoted by Hevi-Duty Electric Co., Milwaukee, from district sales manager of the Cleveland area to vice-president in charge of sales.

H. H. Hewitt, Jr., is now with McCulloch & Sons, Portland, Ore.

E. L. Bartholomew, Jr., for the past 12 years on the teaching staff of Massachusetts Institute of Technology, has accepted an appointment as associate professor of mechanical engineering at the University of Connecticut.

Karl Thomas Aust, who received his Ph.D. in June from the University of Toronto, is now research metallurgist in the X-ray diffraction division of Kaiser Aluminum and Chemical Corp., Spokane, Wash.

C. A. Sellen has been appointed assistant to the general manager of the Reliance Div. of Eaton Mfg. Co., Massillon, Ohio. He joined the division in 1939 as chief metallurgist.

Edgar C. Buckingham, who graduated from the University of Southern California in June, is now employed in the traffic department of Monolith Portland Cement Co. as assistant traffic manager.

Albert G. Haynes is now project engineer in plant engineering department of Koppers Co.'s recently acquired engineering department.

Edward D. Weisert, who graduated in August from the University of Michigan, has accepted a sales engineering position in the Chicago district office of the Haynes Stellite Div. of Union Carbide and Carbon Corp.

Werner Blumenthal, who received his degree from the University of Michigan in June 1950, is now employed as a process engineer with AMI, Inc., Grand Rapids, Mich.

Mark M. Templeton, who for the past two years has been superintendent at the Sheffield, Ala., plant of the Electro Metallurgical Div. of Union Carbide and Carbon Corp., has been appointed assistant to the works manager of the division and will be located in Niagara Falls, N. Y.

After receiving his Ph.D. from Illinois Institute of Technology in June, **Frank A. Crossley** has been appointed director of the department of metallurgical engineering of Tennessee Agricultural and Industrial State College.

Frederick V. Horak has been transferred by Allis-Chalmers Mfg. Co. from West Allis works to become plant metallurgist at the LaCrosse works, LaCrosse, Wis.

C. Donald McLain, formerly with Spang-Chalfant Div. of National Supply Co., is now metallurgical engineer with Western Brass Mills Div. of Olin Industries, East Alton, Ill.

Raymond C. Landstrom, formerly sales representative for the Latrobe Electric Steel Co. in Rockford, Ill., is now vice-president in charge of manufacturing of the King & Hamilton Co., Ottawa, Ill.

Bruce M. Shields, formerly research metallurgist of the South works, Carnegie-Illinois Steel Corp., has accepted a research assistantship at Massachusetts Institute of Technology and will work toward his Doctor of Science degree.

Goldye Cohen Leeds, formerly with I. Stern & Co., Inc., is now a technical writer for the Signal Corps Publications Agency, Fort Monmouth, N. J.

Personals

Anton L. Schaeffler, formerly with the Arcos Corp., has joined Allis-Chalmers Mfg. Co., Milwaukee, as a metallurgical engineer.

William F. Tuff, who graduated from the University of British Columbia this year, is now with the Steel Co. of Canada, Hamilton, Ont., works, in its training program.

Frank P. Denzel has established the Franklin Supply Co., Columbus, Ohio, to distribute welding supplies in central Ohio for Linde Air Products Co. and Metal & Thermit Corp.

Harold D. Wilson has been appointed vice-president of the Gary Steel Supply Co., Chicago. He has been with the company since 1943.

Zay Jeffries, former vice-president of the General Electric Co., has been appointed Leonard Case professor and consultant on education policy of Case Institute of Technology, Cleveland.

F. Wesley Smith, formerly New England manager for D. A. Stuart Oil Co., has opened consulting offices at Holliston, Mass. He will specialize in lubricants and their applications.

After graduating from Case Institute of Technology, **Henry Kopczewski** has been appointed foundry metallurgist in the research laboratory of Apex Smelting Co., Cleveland.

Charles C. Hicks is now supervisor of the engine dynamometer laboratory test engineers for the Ford Motor Co.'s engineering research department, Dearborn, Mich.

C. W. Haynes is on leave from the faculty of the University of Nebraska and will study at the department of metallurgical engineering, Carnegie Institute of Technology, under an Atomic Energy Commission predoctoral fellowship.

Merrick F. McCarthy, Jr., has recently joined the Peerless Foundry Co., Cincinnati, as metallurgist.

William W. Berkey is now an instructor of aircraft structural repair and aircraft heat treatment for the Department of the Air Force at Chanute Field, Ill.

Joseph E. Hagins, formerly with Sheffield Steel Co., Houston, Tex., is now maintenance superintendent for the A. O. Smith Corp. of Texas.

James J. Kubbs, formerly metallurgist of the Modern Steel Treating Co., Cleveland, has accepted a position as metallurgist of the chain division of the Jeffrey Mfg. Co., Columbus, Ohio.

Caterpillar Tractor Co., Peoria, Ill., announces the appointment of **J. R. Munro**, formerly general factory manager, to the newly created position of director of manufacturing; **C. A. Woodley** will be the new general factory manager; **W. L. Naumann** and **Lloyd J. Ely** have been named assistant general factory managers.

R. M. Goldhoff, who received his M.S. from the University of Cincinnati in August, has assumed the position of research engineer in nonferrous metallurgy with Battelle Memorial Institute, Columbus.

John J. Naughton, associate professor of chemistry at the University of Hawaii, has received an appointment as visiting assistant professor of chemistry at Princeton University for the year 1950-1951.

Charles D. Townsend has established Professional Expediting Service, West Hartford, Conn., which offers technical and engineering aid to small companies.

Following completion of a course for graduate engineers at Algoma Steel Corp., Sault Ste. Marie, Ont., **John Harvey Bradbury** has accepted the position of metallographer and is in charge of the metallographic laboratory at Algoma.

Stabilized 18-8

(Discussions start on p. 691)

fact that until relatively recently many producers have had difficulty in obtaining carbon contents regularly below 0.10%.

The extending use, however, of the oxygen lance (and to some extent the introduction of improved electrode controls) is making carbon contents of 0.05% or less increasingly common in steel foundry practice. The general availability of such low-carbon steels can in turn render the argument against titanium very much less convincing — if not completely invalid — and it must, necessarily, make the use of both stabilizing agents very much less in quantity and, in some cases, even unnecessary altogether.

J. F. B. Jackson
Director of Research
British Steel Founders' Assoc.

Melting and Pouring

University, Ala.

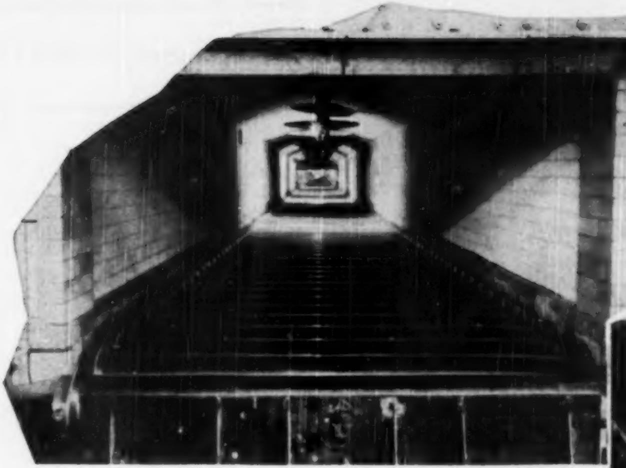
I believe that Mr. Tyrrell's presentation of the comparative merits of columbium and titanium in the fabrication of 18-8 alloys is very concise, and that it also is backed up by a large amount of technical and practical experience. As I was familiar with the titanium-stabilized material in the early stages of its development, it is obvious to many of the old-timers that lack of fabrication and technical skill in the early days of stainless metal had a great deal to do with the unsatisfactory appraisal of titanium.

It is well known that during the past 15 years, thousands of tons of titanium-stabilized alloy has been successfully used in many applications. As Mr. Tyrrell brings out, there is no doubt regarding the great ease of processing the titanium alloy after it has once been melted. One of the chief objections to the titanium-bearing material is the difficulty of melting the alloy as compared to melting the columbium alloy.

E. C. Wright*
Head
Dept. of Metallurgical Engineering
University of Alabama

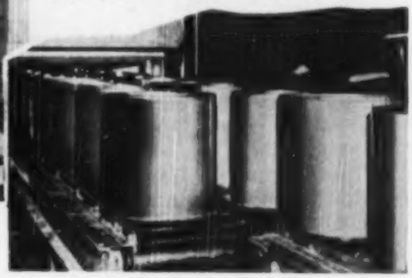
*Editor's Note — Mr. Wright was for many years chief metallurgist of Ellwood City (Pa.) plant of National Tube Co.

(Discussions continued on p. 744)



◀ A battery of Inconel conveyor rolls in a brass strip annealing furnace, Scovill Mfg. Co., Waterbury, Conn. The furnace was fabricated by SURFACE COMBUSTION CORP., Toledo, Ohio.

Input end of brass annealing furnace showing coiled brass strip resting on Inconel furnace pans at Scovill Mfg. Co., Waterbury, Conn. These circular pans were fabricated by THE PRESSED STEEL CO., Wilkes-Barre, Pa. ▼



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Melting of 18-8 Ti

(Continued from p. 742)

SHEFFIELD, ENGLAND

I am in almost complete agreement with Mr. Tyrrell's conclusions; my only real objection to the use of titanium as a stabilizer instead of columbium in austenitic chromium-nickel stainless steels is in connection with highly polished sheets. A mirror finish is frequently demanded and it must be admitted that titanium-stabilized steel sheets do not yield such satisfactory results as those produced from columbium-stabilized steels. Where this high degree of surface finish is not required, however, the titanium-bearing steels are in all other respects quite equal in quality and general properties to those stabilized with columbium, and this applies particularly to steel castings, many thousands of which have been produced by my own company.

Our melting units comprise both high-frequency and electric-arc furnaces, the former being employed in the manufacture of stainless steel castings and the latter for the production of ingots.

Induction Melting—The titanium is added as ferrotitanium in the furnace and we use the 40% Ti grade and *not* the 20 to 25% Ti grade, since a lesser amount is needed and the bath is not chilled so much. The alloy should be added in lump form as the fine stuff gets entrapped in the slag, which should be thinned by the addition of some form of calcium alloy (Ca-Si or Ca-Si-Mn) at the same time as the titanium addition. The heat generated from the oxidation of the calcium together with the thin slag formed assists the lump ferrotitanium to sink into and dissolve in the molten metal. *Before* the titanium addition is made the temperature of the bath should be raised to that finally required, as it is essential to pour from the furnace *immediately* after the alloy has disappeared into the melt.

Loss of titanium in the ladle becomes serious only when making very small castings *(a)* because of the degree of superheat necessary, *(b)* by virtue of the time factor involved in shanking small castings and *(c)* the actual use of "open" shanks. Therefore, when small castings are being made, a surplus of titanium must be added over and

(Continued on p. 746)

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Melting of 18-8Ti

(Discussions start on p. 691)

above the theoretical amount that would be regarded as sufficient for the much larger ingots teemed through a ladle nozzle.

The recovery from titanium-bearing scrap is practically *nil*. That from ferrotitanium varies with melting practice. To minimize titanium losses or, rather, to obtain a more or less constant loss value, the melt should contain about 1% each of silicon and manganese, and be deoxidized by some powerful deoxidant before the titanium is added. Use of a Ca-Si-Mn alloy for such deoxidation appears to improve the fluidity of stainless steels of the austenitic type. Generally, we recommend the addition of 0.8% titanium to the melt to retain 0.4% in the solid steel, that is, there is a loss of 50% of the titanium, but the percentage loss becomes less with higher initial titanium additions, as would be expected.

Titanium does not appear to have much influence on the fluidity of the steel at the high temperatures needed for the successful running of steel castings and, as mentioned, we always aim to keep the silicon and manganese around 1% each.

As regards surface quality of the castings, no unduly large patches of slag are encountered if the slag is held back by a skimmer during pouring. As regards suitability for use, our experience is that titanium-stabilized steels are just as resistant to attack as columbium-stabilized steels and, indeed, under certain conditions are perhaps better.

Basic Electric-Arc Melting — In our early experiments concerning the production of ingots from steel melted in the basic electric-arc furnace (4½ tons capacity), exceptionally high and completely uncontrollable losses of titanium resulted from adding the ferrotitanium in the furnace. Consequently, we developed a simple method of making the addition during the pouring of the steel into the ladle. A hopper mounted on a frame, which straddles the furnace pit, is now used. A lever arrangement permits the opening of a ball valve and through the aperture at the bottom of the hopper a constant flow of the ferrotitanium (⅛-in. mesh, 40% Ti grade) occurs, in alignment with the stream

(Continued on p. 748)

Melting of 18-8Ti

(Discussions start on p. 691)

of molten metal issuing from the furnace. The two streams thus mix as they flow into the ladle. A slag-trap door is in position in the furnace so that practically all the slag is held back until the hopper is empty; in this way, minimum titanium is lost in the slag. Subsequently, of course, slag flows into the ladle to give the desired covering.

Adding the equivalent of say 0.60% titanium, between 0.30 and 0.40% of the element can be expected in the solid steel, that is, the actual yield may vary from 50 to 66% according to the bath condition at the time of tapping. No titanium recovery is possible from titanium-bearing scrap. There is no appreciable variation in titanium content from ingot to ingot in casting ten ingots each weighing 1000 lb.

Before the steel is poured into the ladle, the bath temperature is raised to 2970° F. in order to compensate for the cooling effect (about 100° F.) of the titanium addition. At normal ingot pouring temperatures, the titanium-bearing austenitic steels made from virgin materials appear to be somewhat more viscous than similar steels free from titanium, but this decrease in fluidity has not been evident in the many heats we have produced from 100% stainless steel *scrap* charges involving the use of the oxygen lance. Our usual procedure is to teem our ingots through a 1¼-in. nozzle ladle into a tun-dish also having a 1¼-in. nozzle.

All our titanium-stabilized stainless steel from the electric-arc furnace has been rolled into bar, sheet and strip which, in most instances, has been subject to A.I.D. inspection. Complaints have been few and since the employment of our oxygen technique almost nonexistent.

Provided that the carbon content is sufficiently low and the titanium not greatly in excess of that needed for stabilization, excellent results are obtained and the steel is definitely as good as that stabilized with columbium. By using the oxygen lance and starting with 100% stainless scrap charges, we regularly produce steels of less than 0.05% carbon, which results in a superior quality material when stabilized with titanium.

EDWIN GREGORY
Director
Edgar Allen & Co., Ltd.

(Discussions continued on p. 750)

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Low-Carbon 18-8

(Discussions start on p. 691)

Lower Carbon Contents

BALTIMORE

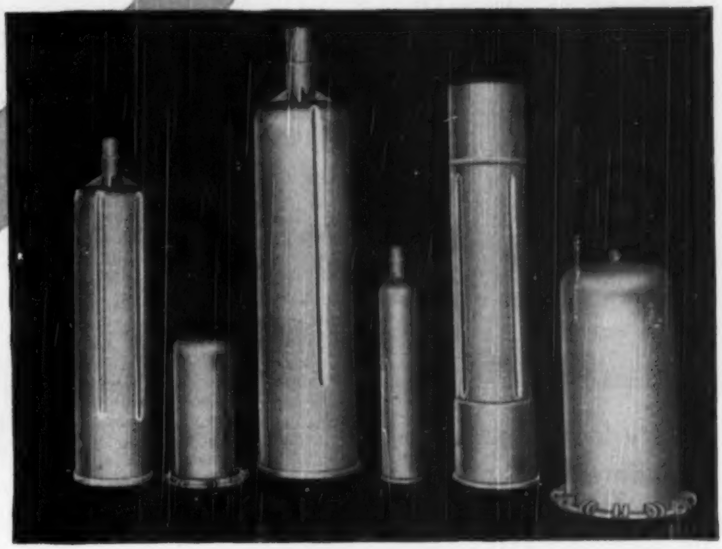
The conservation of columbium, which Mr. Tyrrell has so ably discussed, is of special interest in view of the likely large increase in demand for this element for military purposes. For applications of the type described, involving exposure to hot exhaust gases up to 1500° F., there seems to be no reason why Type 321 titanium-stabilized steel cannot replace the columbium-bearing Type 347.

It has been pointed out that for inert-gas-shielded arc welding, Type 321 is superior to Type 347 because of its lesser tendency to develop "hot short" cracks. This may be explained on the basis of the difference in composition balance of the two alloys, which is such, on the average, that Type 321 weld deposits will contain some delta ferrite, while Type 347 deposits will not. The presence of this phase in austenitic welds is known to inhibit their normal tendency to "hot short" cracking. (For further information, the reader may refer to the article by R. David Thomas, Jr., in *Metal Progress* for September 1946.)

The difference in forming characteristics can be attributed in part to the fact that since columbium forms a more insoluble carbide than titanium, annealed Type 347 generally has more undissolved carbides in the matrix than Type 321, which makes it slightly stiffer. This is evident in the slightly higher average tensile and yield strengths shown for annealed Type 347 in various publications.

Another way of conserving columbium which is not mentioned in Mr. Tyrrell's article is through the use of the extra-low-carbon (0.03% max.) alloys. These have been available commercially for several years and have proven themselves especially useful in applications such as welded vessels and other articles used in the chemical industry involving short exposure in the range of carbide-precipitation temperatures. For applications where service temperatures do not exceed 800° F., Types 304 ELC, 316 ELC and 317 ELC may be used without fear of weld decay, as their low carbon content will prevent harmful car-

(Continued on p. 752)



Low-Carbon 18-8

(Discussions start on p. 691)

bide precipitation during the short heating period used in welding. Laboratory tests in extremely corrosive mediums have shown that the low-carbon stainless steels are equal to their columbium-stabilized counterparts in the as-welded condition and this has been confirmed in practical field experience (A.S.T.M. Special Technical Publication No. 93, 1950, p. 56-80, 87-100). The mechanical properties of these alloys up to 800° F. are similar to those of Types 304 and 316, being slightly lower with the lower carbon content. The low-carbon alloys are readily formed and may be satisfactorily welded either by resistance or by all types of shielded-arc welding with metal electrodes. The addition of these alloys to the roster of stainless steels, together with a much improved knowledge of manufacturing and fabricating Type 321, should go a long way toward relieving the drain on our columbium resources.

F. K. Bloom
Supervising Metallurgist
Research Laboratories
Armco Steel Corp.

Welded Tubing

Union, N. J.

It is agreed here that the conservation of columbium is a worthwhile endeavor. However, many of us believe that the subject should be discussed on a broader basis than was attempted by Mr. Tyrrell, who understandably limited his paper to suitability of the two most common types of stabilized steel for aircraft applications. The broader discussion that we have in mind would include consideration of the following alloys in addition to Types 321 and 347: *(a)* the recently developed steels with carbon contents of 0.03% max., *(b)* columbium-stabilized steels with carbon contents greater than 0.03% but lower than in the current production of Type 347, *(c)* steels stabilized with columbium contents of eight times the carbon content — as widely used during World War II — instead of the usual ten times, and *(d)* tantalum-columbium steels.

As manufacturers of welded tubing, we had a special dispensation during the last war to use Type 347 exclusively, even though 321 might have been specified. At that time,

(Continued on p. 754)

Stainless Tubing

(Discussions start on p. 691)

this mill and many similar mills were using the atomic hydrogen arc-welding process, with which the manufacture of Type 321 tubing was a hazardous and difficult undertaking, especially in gages heavier than 0.049 in. The defects that developed when Type 321 was welded with atomic hydrogen equipment were not those described by Mr. Tyrrell for Type 347, but they were serious enough so that the risk in welding was not worth the effort required to overcome it. Since that time, most manufacturers of welded tubing have installed some adaptation of inert-arc welding, and subsequent experience has shown that 321 is much less hazardous to weld than 347, for the reasons described by Mr. Tyrrell.

If the adoption of Type 321 becomes more widespread we can expect some problems involving the difficulty of final heat treatment for adequate stabilization, welding as it relates to a stabilized end product, and seams that occur as a result of stringers of titanium or titanium compound and their effect on the ductility of manipulated parts.

J. A. Deitrich
Manager, Alloy Tube Division
The Carpenter Steel Co.

More on Welded Tubing

Cleveland

The statements in Mr. Tyrrell's article comparing the welding characteristics of the two alloys, 321 and 347, are of particular interest to us as producers of welded tubing. A continuous automatic process is always used for welded tubing but the welding operation itself has changed over the years. During this period, the major percentage of production has been confined to 347, with the production of 321 limited to trial lots or small quantities.

The first welding process to be applied to stainless tubing was resistance welding, and we found no appreciable difference in welding speeds and technique or weld quality between the two steels. Acetylene welding was also used with apparently equal ease on the two alloys.

With the trend to arc fusion welding, a definite difference in welding characteristics was found.

(Continued on p. 756)

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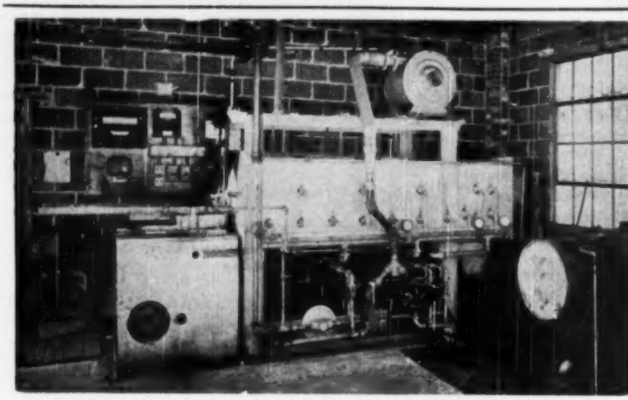

Stainless Tubing

(Discussions start on p. 691)

depending on the specific process used for the automatic continuous welding of the various types of stainless tubing. Early experience was based on atomic hydrogen welding, and it was found necessary to discontinue the use of this process on Type 321 because of the excessive number of gas pockets and pits formed in the welding operation. This process was used extensively for 347 tubing and considerable footage was produced before and during the war years in a wide range of sizes. Repair welding is not normally done on welded tubing; consequently scrap losses were excessively high on Type 321, making it uneconomical to produce welded tubing in this analysis.

We have subsequently installed inert-gas arc welding as a replacement for atomic hydrogen welding. Major production has been confined to Type 347, and increased welding speeds, as compared with atomic hydrogen welding, have been possible on this alloy. There has been very little footage made in Type 321, as the demand appears to be wholly for 347, probably because 321 was heretofore not readily available in welded tubing. Experimental runs on 321 indicate that weld quality with inert-gas welding should be equivalent to that produced in 347. Welding conditions applicable to the two alloys are practically identical, with no difference in welding speed or control of the operation.

Because of the definite shortage of columbium and the lower cost of the titanium steel, we anticipate a trend to 321 in welded tubing for applications where heat resistance and freedom from carbides are the primary considerations. The use of inert-gas arc welding should promote the use of 321 tubing as a replacement for 347 tubing.

J. S. Adelson
Chief Metallurgist
Steel and Tubes Div.
Republic Steel Corp.

Seamless and Welded Tubes in Britain

Birmingham, England

In the manufacture of tubes we find no very significant differences between the two types of stabilized stainless steel. Seamless tubes in

(Continued on p. 758)

Stainless Tubing

(Discussions start on p. 691)

these materials are made here by hot extrusion and cold drawing, and for compositions otherwise similar we find that Types 321 and 347 can be treated alike as regards hot and cold working operations; they give the same mechanical properties in comparable finished conditions. Techniques developed originally for the titanium-stabilized steel are applied without change to the columbium-stabilized variety. Type 321 steels sometimes contain nonmetallic inclusions that make polishing more difficult and we have on occasion found it easier to get a good mirror finish with Type 347, but this is not very often the determining factor in the choice of material.

Welded tubes are made from strip by the atomic hydrogen process in both classes of steel; more correctly, the demand for the welded tube in Type 347 is small and our experience is confined to some thousands of feet made on an experimental basis. We found that the two steels could be treated alike as regards welding speed, and that welded tubes could be subsequently cold drawn with equal facility to give the same mechanical properties in the softened condition or in the as-drawn condition after comparable amounts of reduction. In that relatively limited experience we had the impression that the columbium-stabilized steel formed a more fluid pool under the arc, and that the finished welds looked rather smoother, but we do not know whether that is generally true. In atomic hydrogen welding we did not observe the differences mentioned by Mr. Tyrrell in connection with inert-gas welding, although we interpret that section of his paper to mean that he recognizes that those differences may be due to variations in composition other than the simple presence of the one stabilizing element or the other.

Altogether, therefore, our experience indicates that Types 321 and 347 are alike as far as tube manufacture is concerned, and that the choice is a matter of initial cost, availability, and of serviceability in conditions peculiar to final use.

J. W. Jenkin
General Manager
Dept. of Development & Research
Tube Investments, Ltd.

(Discussions continued on p. 760)

Stabilized 18-8

(Discussions start on p. 691)

Further British Experience

Sheffield, England

Although in the development of stabilized austenitic stainless steels in Britain additions of many elements were proposed and tried, the type became essentially a titanium-bearing steel, to the exclusion of practically all other of the variously proposed additions. Columbium did not feature in the earlier attempts to obtain a steel immune from intergranular attack.

The earliest aircraft specifications for this type of material, for example, DTD 171 (Nov. 1931), although including a bend test on a sample boiled in the copper sulphate – sulphuric acid solution after reheating for 30 min. at 1200° F., included titanium in the list of additional elements which may be present at the option of the steelmaker, but it did not include columbium, nor did a re-issue of the specification (Nov. 1932). It was not until a further issue in Oct. 1941 (DTD 171B) that columbium was included.

It can be taken, therefore, that there is considerable and extended experience with titanium-stabilized steels in Britain and that very large quantities have been successfully used in aircraft, chemical, textile and kindred industries.

In the American Types 321 and 347 the carbon content is limited to 0.08% and the addition of the metals titanium and columbium respectively are related numerically to the carbon content. In general the British specifications do not restrict the carbon content to such low values; for example, the Air Ministry specifications allow 0.2% max. and the British Standard "En Series" limits the carbon content to 0.15% max. for En 58-B, C, F and G, of which B and C contain titanium and F and G columbium. Both specification authorities require that the respective materials shall satisfy the boiling copper sulphate – sulphuric acid test and both also specify a proportionate addition of the stabilizing element. There are slight differences in the proportions of the stabilizing elements now required by the different specifications.

At the works where the writer is engaged, experience shows that the melting loss of titanium is not

(Continued on p. 762)

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Stabilized 18-8

(Discussions start on p. 691)

constant but varies probably according to the oxidation of the melt, the bulk and consistency of the slag, and so on. With a normal addition of 1% titanium the residual titanium in the finished steel will generally lie between 0.65 and 0.85%, although both higher and lower figures do occur. It is always found that no titanium is recovered from titanium-bearing scrap included in the charge. These remarks refer to electric-arc furnace melts.

The carbon contents of these steels are usually appreciably lower than the specified maximums, but, irrespective of the final analysis, each cast is tested for resistance to intergranular corrosion before it is allocated and put into production. This "cast test" does not replace the tests carried out on the finished products, which are tested strictly in accordance with the relevant specification, but such "cast tests" are regarded as *the* criterion of the suitability of the cast. The analysis, as such, is not an infallible indication. It has not been found that titanium is progressively lost during the teeming of ingots from 20-ton arc furnace casts.

By comparison, the columbium yield is not so variable and about 80% of the amount added is regularly retained and something like 75% is recovered from the scrap.

Perhaps the most striking difference between titanium and columbium additions is in their respective effects on the fluidity of the molten steel. The addition of ferrotitanium seems to cause a "thickening" so that the metal does not run so freely and it has been found that whereas a 1⅞ or 2-in. dia. nozzle is necessary for adequate teeming of the titanium-bearing steel, the columbium-bearing type can be satisfactorily teemed through a 1½-in. dia. nozzle. As a result of the "thickening" effect, the surfaces of the titanium-treated steel ingots are not so good as the columbium-treated type, although it will be obvious, in view of the large tonnage of the titanium-treated steels that has been made, that the yields are commercially economical. That apart, the materials are not noticeably different in normal hot working.

In respect to cold rolling, no significant difference seems to exist

(Continued on p. 764)

Stabilized 18-8

(Discussions start on p. 691) between the work hardening rates of the two types of steel if the chromium-nickel ratio is the same. However, there seems to be a clear difference in the bend tests — both close and reverse — especially after the heavier reductions.* This indication of reduced ductility in the columbium-bearing steel is not similarly reflected in the elongation values, whereas Mr. Tyrrell's tests show lower elongation values for the columbium-bearing steel at temperatures up to 1000° F. These observations, however, taken in conjunction with the two stampings shown in Fig. 1 of the paper, do indicate some comparative lack of ductility in the columbium steel.

There appears to be no particular preference among welders for either type of stabilization. In any event, several instances have been observed where the two types have been satisfactorily welded to one another in the construction of certain fabricated parts. There appears to be in this country a strong bias among welding rod makers in favor of columbium-stabilized rods.

Mr. Tyrrell's observation on the relative resistance to oxidation of the two types at temperatures of about 1300° F. is interesting. A ferrotitanium alloy commonly in use in this country and containing approximately 23% titanium will generally contain 7 to 10% aluminum. If it can be assumed that the alloy used in America is of a similar type, may it not be that the improved oxidation resistance of the titanium-bearing steel is influenced by its aluminum content? Mr. Tyrrell's observation does not seem to have been generally noted in this country.

Because of the "scatter" frequently found in creep test results, extensive data are necessary for any reasonable differentiation to be made, but, from the somewhat limited data at his disposal, the writer would have *(Continued on p. 766)*

*Editor's Note: The writer of this letter, Mr. H. Allsop, has submitted extensive tabular data showing results of tensile, close bend and reverse bend tests on three heats of each type of stabilized steel. Each steel was tested after nine different reductions by cold rolling. A copy of Mr. Allsop's data will be sent free upon request to the Editor of *Metal Progress*.

Stabilized 18-8

(Discussions start on p. 691)

thought that the columbium type was usually superior in this respect.

There is no doubt that, with the exception of the special high-temperature alloys for specific purposes, and welding rods and some castings, practically all the needs of those industries requiring stabilized stainless steel can be adequately met by the titanium-bearing steels. That Britain has fulfilled her needs in these directions for many years without serious recourse to columbium-containing steels is proof enough of the statement.

H. Allsop
Director of Research
Brown, Bayley's Steel Works, Ltd.

Stabilized Stainless Plate

Coatesville, Pa.

The experiences of Lukens Steel Co. in the production of plates and in the hot and cold forming of heads from plates of Types 347 and 321 stainless steel are very much in line with those outlined in Mr. Tyrrell's paper.

Type 321 is easier to roll into plate since it has greater plastic flow at rolling temperatures than 347. Less difficulty also is encountered in forming heads of 321 than of 347, due no doubt to its greater ductility at both high and atmospheric temperatures.

Type 321 exhibits good welding characteristics as well as good resistance to high temperatures, and is at least comparable to Type 347 in these respects.

It is the writer's opinion that, in view of the shortage of columbium, promotion of Type 321 should be encouraged where weldability, rather mild corrosion resistance, formability, and high-temperature oxidation are important factors.

J. G. Althouse
Metallurgical Engineer
Lukens Steel Co.

More on British Aircraft

Edgware, England

I am in substantial agreement with Mr. Tyrrell's lucid and well-put argument for the use of titanium-stabilized and heat resisting alloys of the austenitic chromium-nickel family. For American readers any comment probably should be prefaced by a note as to the British

(Continued on p. 768)

British Aircraft

(Discussions start on p. 691)

equivalent of the American Types 321 and 347, and their changes in composition during the past dozen years. This is summarized in the accompanying table.

It will be noted that in the first two versions no mention is made of a stabilizing element, although such was usually necessary—particularly with the higher carbon casts. Freedom from intergranular embrittlement was safeguarded by a pickle-bend test.

Incidentally, even with the latest compositions the pickle-bend test is still a mandatory requirement. It will be appreciated, however, that a test of this nature can only control freedom from embrittlement at the temperature and conditions of test and need not necessarily indicate proof of satisfactory behavior at other temperatures. A test to cover all conditions is deemed impracticable and for this reason service experience is of greater importance.

In British specifications the analysis range is generally wider than in the American counterpart mainly because greater control is exercised in other directions, either by heat treatment and/or specified mechanical properties. With the type of steels in question, however, the composition range has gradually been tightened and is now comparatively closely controlled—although carbon content, a most important variable, is still wider than in Types 321 and 347. Generally, while no manufacturer produces a steel approaching the maximum permissible, the carbon content of the British steels is somewhat higher than the American, being of the order of 0.07 to 0.12%. This higher carbon range makes stabilization against "weld decay" or intergranular embrittlement more important, and demands the use of carbide formers such as titanium or columbium. Hence the change to the postwar composition shown in the table.

Preference for Titanium in Welded Structures—Before the 1939 World War, titanium was almost universally used for stabilizing stainless steels. Although the use of columbium is increasing, owing chiefly to American influence as a result of the consumption of large quantities of American sheet during the war, titanium is still the preferred and more generally used stabilizer. Briefly, the main reasons for this are: Firstly, because the British are conservative in outlook and are slow to change already well-established practice; secondly, columbium is more expensive, in short supply, and is required for more important applications; thirdly, less titanium is required; and fourthly, the fabricator, and in particular the welder, prefers titanium.

This last may be due, to some extent, to inexperience in welding with columbium-bearing material, although columbium-bearing welding rod and fluxed wire have been in use for many years. The fact remains, however, particularly with thin-gage aircraft sheet, that more care has to be exercised to produce a clean, uniform weld, and greater difficulty is experienced in repairing welds in columbium-bearing material. The difficulty appears to be emphasized when welding columbium-stabilized material of widely dissimilar thicknesses.

From these remarks it must not be inferred that columbium-stabilized material cannot be used for welding purposes; much of it is already in general use. On the other hand, wherever a difficult weld cannot be avoided by design changes, there does seem to be a preference for titanium. *(Continued on p. 774)*

Compositions of British Stainless Steels for High-Temperature Weldments

Element	British Equivalents to Types 321 and 347				DTD493
	Pre-1939 War	Wartime Changes		Postwar	
		First	Second		
Cr	>12.0	16.0/20.0	16.0/20.0	16.0/20.0	20.0/26.0
Ni	6.0/20.0	7.0/12.0	7.0/12.0	8.0/12.0	14.0/22.0
C	<0.20	<0.20	<0.20	<0.16	<0.20
Si	>0.20	>0.20	>0.20	>0.20	>0.20
Mn	<1.00	<1.00	<1.00	<1.00	<1.00
S	<0.05	<0.05	<0.05	<0.045	<0.05
P	<0.05	<0.05	<0.05	<0.045	<0.05
Ti	N.S.	N.S.	>0.50*	>5 × % C†	>0.50*
Cb	N.S.	N.S.	N.S.	>10 × % C†	N.S.

*Not less than 5 × % C. †Alternative.

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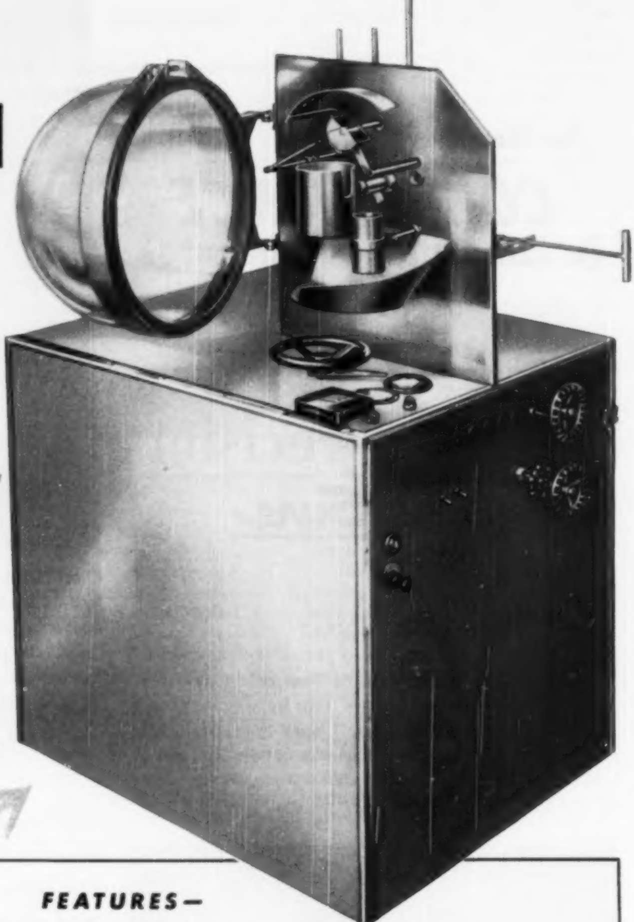

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British Aircraft

(Discussions start on p. 691)

The main disadvantages in the use of titanium are oxidation losses at the weld, and also that part of the titanium may be present in the steel as nitride and so does not exert any stabilizing influence.

Until comparatively recently the majority of experience in fusion welding has been with gas welding and later with the metallic arc where oxidation losses are of some importance. By the increasing use of inert gas atmospheres, such as are produced by atomic hydrogen and the argon arc, this criticism is of less significance.

Effect of Lower Carbon Content — There is a gradual leaning in this country toward a lower carbon stainless steel of the order of 0.03 to 0.05% C. This will eliminate, for many applications, the need for stabilization. This trend will help in many respects, in that steelmaking will be simplified, forging and rolling made easier, as well as fabrication simplified in the consumer's plant. Moreover, a higher standard of finish, free from titanium segregation so often disclosed toward completion of manufacture, will also be possible.

There is, however, one distinct drawback from the aircraft designer's point of view. As part of the design procedure of structural components a design factor is employed based either on 0.1% proof stress (or on ultimate tensile stress, which ever is the lower). In the case of softened stainless steel the 0.1% proof stress is the operative value, and with existing specifications the minimum figure is 13 to 15 tons per sq.in. (29,200 to 33,600 psi.). With stainless steels containing 0.03% carbon this property would be reduced to the order of 10 tons per sq.in. (22,400 psi.) — a serious reduction where weight is of paramount importance.

Elevated Temperature Properties — With the introduction of gas turbine engines a further influence comes into play in regard to properties at elevated temperature. Hitherto the emphasis has mainly been on the use of a stable and scale resisting steel, but with gas turbines a wider field of application becomes available and some improvement in hot properties is of considerable interest.

For example, the use of either titanium or columbium can have a pronounced effect, given a suitable thermal treatment, and will provide adequate creep performance for many applications where previously a more expensive and complex steel has been necessary. In this direction it is suggested that more effort be put into research to determine a useful general-purpose and comparatively cheap alloy with heat and scale resistance for use in turbine parts where temperatures are relatively moderate. Much work is already being done, one instance being the use of molybdenum-bearing steels for this purpose, but the scope is wide.

A considerable quantity of the 18-8 type of heat resisting steel (DTD571) is used in sheet metal parts such as tail pipes and extensions, rear cones, deflector and baffle plates on the turbine and, wherever possible, for exhaust manifolds and collector rings on piston engines. This steel is quite adequate for temperatures up to 700° C. (1300° F.). For higher temperatures a steel somewhat similar to the American Type 310

(Continued on p. 776)

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

Required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (39 U.S.C. 233), of **Metal Progress,** published monthly at Cleveland, Ohio, for October 1, 1950.

1. The names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio; Editor, E. E. Thum, 7301 Euclid Ave., Cleveland 3, Ohio; Managing Editor, E. E. Thum, 7301 Euclid Ave., Cleveland 3, Ohio; Business Manager, W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.

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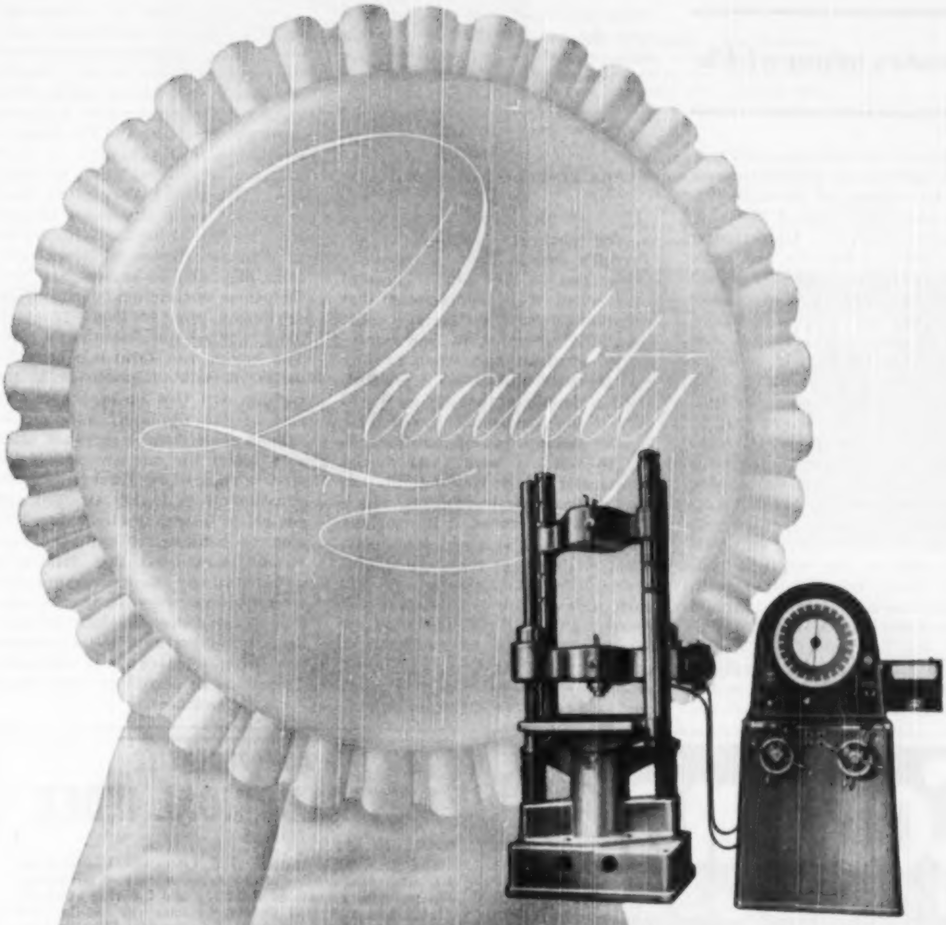
W. H. Eisenman,
Business Manager.

(Seal)

Sworn to and subscribed before me this 1st day of October, 1950.

Genevieve G. Fitzgerald
Notary Public.

(My commission expires March 26, 1952.)


Quality

Conservation of Cb

(Discussions start on p. 691)

is used, namely, the DTD 493 shown in the last column of the table. Its higher chromium content improves the scale resistance; temperatures up to 850°C. (1550° F.) are quite permissible. It should be mentioned that this specification is also being brought into line with the 18-8 type, in that the stabilizing elements titanium or columbium are to be specified in relation to carbon content.

High-Strength Alloys at Elevated Temperatures — With regard to titanium and columbium in high-strength, high-temperature applications for gas turbine rotating blades, and in like situations, British practice differs fundamentally from American. In this country universal use is made of the wrought "Nimonic" alloys (nickel-base with 20% chromium, containing titanium and aluminum as precipitation elements) and there does not appear to be any likelihood of a change for established engines, at least in the immediate future. Other alloys are being developed and tested; however the only alternatives contain high proportions of cobalt and for this reason are not encouraged.

K. W. Clarke
Central Laboratory
De Havilland Aircraft Co., Ltd.

Steps Toward Conservation

Sheffield, England

The challenge implicit in Mr. Tyrrell's article is a particularly useful one to face at the present time when it is appreciated that columbium would be in very short supply if a full-scale war emergency occurred and when in any case its better utilization is prudent.

It is significant that during World War II the Germans reserved their slender stock of columbium for adding to welding wire (and maybe plate material) for welding only the most critical chemical vessels, which presumably operated at the highest temperatures. British experience bears out the fact that columbium-bearing stainless steels are preferable under such conditions, but there would be no hesitation in adopting titanium-stabilized steels in a national emergency when economics and the life of a plant could be regarded as secondary.

In what way is columbium-stabilized steel or welding-rod material superior to titanium-stabilized? The answer is twofold. Firstly, titanium oxidizes more rapidly than columbium when the steel is molten during arc welding and the titanium carbide will dissociate to form titanium oxide and quite probably titanium nitride. Very often there is present some aluminum derived from the ferro-alloy, which oxidizes to alumina. Some additional alumina may also be present and thus inclusions in titanium-bearing steels are often rich in both types of oxide, besides some titanium nitride. The nitride can form a continuous series of solid solutions with the carbide and this in turn can give rise to the titanium cyanonitride, salmon-colored cubic crystals often seen under the microscope. If the steel containing these unwanted constituents is highly stressed and subject to fatigue in alternating tension or bending, it has been reasonably contended that failure is promoted by these metallurgical stress-raisers. For this reason some British valve steels for internal combustion engines have to be supplied free from all titanium additions. Columbium is permitted, and indeed

(Continued on p. 778)

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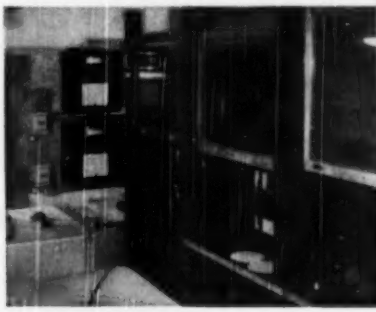

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Conservation of Columbium

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is added in small quantities, with much benefit, to eliminate progressive embrittlement.

Turning now to arc welding, when using columbium we find that the columbium carbide is remarkably stable even when the metal is molten, and that the weld metal contains about 75 to 85% of the expected columbium content. Recent work has shown, however, that the excess columbium (over and above that required to combine with the carbon present) combines with the iron and silicon present to form new brittle intermetallic phases, the incidence of which seems to be one of the main causes of weld-metal cracking in austenitic steels of the 347 type. A forthcoming publication by E. Bishop and W. H. Bailey will deal with this aspect of the matter, but in passing it is highly probable that some of these phases were present in the 347 steel used by Mr. Tyrrell, and may have influenced his formability tests, because on the average 85% more columbium was used than was needed to combine with the carbon alone. Whether titanium in excess produces similar intermetallic phases is at present under investigation in my laboratory. The most important deduction to be drawn is that *better* results will be obtained with some columbium-bearing steels with *less* columbium for a given carbon content, thereby saving the rare element and improving the performance of the component. In some steels, it is desirable to reduce the silicon content as well to below 0.25%.

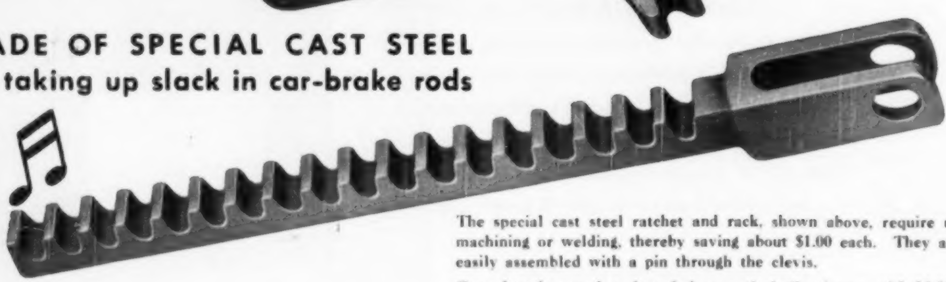
Recent British work shows that some of the well-known gas-turbine blade steels containing up to 4% Cb would be improved if this content were lowered. The fact that weight-for-weight replacement by some tantalum shows no drop in performance proves this; otherwise the (Cb + Ta) content would need to be increased above 4% total because approximately twice the weight of tantalum is required to replace a given weight of columbium on the likely basis of an atom-to-atom substitution.

It appears that the proper approach to columbium conservation might well be along the following lines:

1. To use titanium-stabilized steels wherever possible.
2. To examine critically the present steels containing columbium and to reduce the rare element content, with likely advantage in some cases.
3. To explore the partial substitution of columbium by tantalum, which is expected to be quite successful for most applications, with the possible exception of critical arc-welded fabrications. (A ratio of 1 Cb to 2 Ta may ultimately be feasible.)
4. To reserve the columbium supplies for those critical materials and applications where an ample case has been proved, if necessary, by fresh observations.
5. To foster "good housekeeping" by tighter regulations governing the segregation and return of scrap that contains columbium and, if necessary, to arrange on a national basis for clippings or turnings to be degreased and remelted into ingot form, either for direct use or for remelting, using high-frequency induction furnaces so that carbon pick-up is obviated.

It would appear useful for atten-

(Continued on p. 780)



Conservation of Cb

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tion to be focused on these possibilities, and it will be of great interest to note what measure of agreement can be reached rapidly.

DONALD A. OLIVER
Director of Research
William Jessop & Sons, Ltd.

Summarizing Statements by the Author, J. F. Tyrrell

SAN DIEGO, CALIF.

The editors of *Metal Progress* have asked me to summarize the topic "Conservation of Columbium" by citing highlights of the discussion, without commenting individually on the many valuable contributions. In such a summary I would give priority of place to the matter of service performance in specific applications. Many of the commentators have written from this point of view; the sum total of their discussions represents a sufficient basis for definite conclusions.

The broad conclusion is that columbium-bearing alloys can almost always be replaced successfully by alloys containing less columbium or no columbium. Usage of less critical alloys is not only being discussed but is long-standing practice in Britain and is now being widely adopted in the U. S.

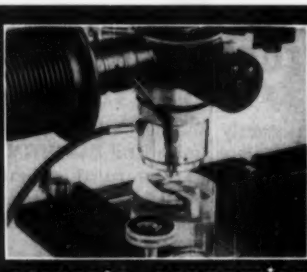
For aircraft components in which columbium-stabilized stainless steel has been found satisfactory, titanium-stabilized steel can be used with no apparent effect on service life and with either no effect or a beneficial effect on productivity. The need for stabilization has been discussed pro and con from the standpoint of selection criteria and service performance. In this summary, I would merely emphasize J. B. Johnson's brief statement that pickling causes embrittlement of unstabilized steels. Aircraft components — particularly in military planes — are cleaned periodically for inspection and weld repair by immersion in strong acid solutions, a routine procedure sometimes required at temporary repair stations. In this exaggerated sense, aircraft parts *do* "fly through acid solutions", and these solutions *do* cause intergranular corrosion and embrittlement of unstabilized steels.

Going beyond my original thesis concerning columbium conservation in stainless steel, several British writers have questioned the need for columbium in gas turbine blades and have referred to the successful use of titanium as a hardener in these superalloys. Specific study of such applications might well be considered one of the next tasks because a sudden disruption of shipping schedules could seriously endanger production of jet engines for military aircraft.

In regard to chemical applications, my original article contained a gross misstatement concerning the use of titanium-stabilized steel in the chemical process industries. Well-qualified discussers have pointed out that Type 321 steel is not only satisfactory for a great many uses in the chemical industry but, in particular, has given completely satisfactory service in many items of plant equipment serving in contact with nitric acid. It is well to have the record corrected on this important matter. Also, it is comforting to know of the superior service performance of unstabilized 18-8 with carbon less than 0.03% in chemical process solutions.

On the production side, two

(Continued on p. 782)



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Conservation of Cb

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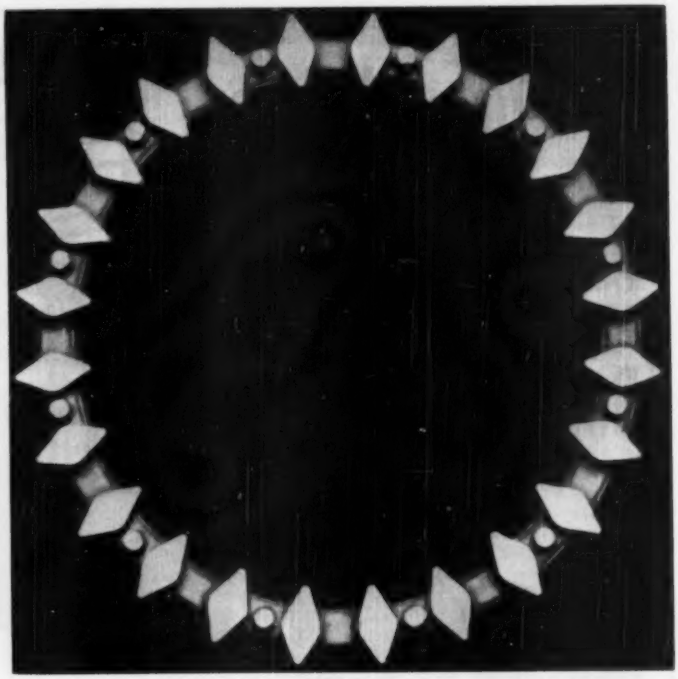
principal problems have been dealt with in discussion — inclusions in wrought material and melting practice in the foundry. Regarding inclusions, the most hopeful comment has come from D. H. Wiese and H. W. Cooper. I can confirm their statement that much progress has been made in cleaning up the titanium-stabilized steel. During the last two years, Solar Aircraft metallurgists have frequently found that 321 and 347 can no longer be distinguished by their inclusion contents, as shown by routine metallography on random samples. Prior to about 1948, and especially during the war years, careful microscopic examination would usually indicate whether any given sample was 321 or 347.

The decrease in inclusion content of 321 steel is a credit to the ingot producers. Stainless steel foundries are also making a commendable approach to their production problems, and E. Gregory's

(Continued on p. 784)



Fuel Manifold for the Westinghouse J34 Turbojet Engine. Casting, about 15-in. diameter, made from titanium-stabilized steel

Conservation of Cb

(Discussions start on p. 691) description of the melting practices used at Edgar Allen & Co., Ltd., should be of specific value to American foundrymen.

Solar Aircraft Co., using induction furnaces, has developed a casting process generally similar to that described by Dr. Gregory. However, to eliminate the excessive dirtiness and low fluidity normally associated with Type 321, Solar has devised modified alloying practices that eliminate most of the detrimental impurities. The process, for which patent is pending, produces an improved casting alloy within the specification range of Type 321 but which is easier to cast than Type 347 and is less subject to the formation of hot tears.

A fuel manifold for the Westinghouse J34 turbojet engine is shown in the illustration on page 782. In previous castings of this part, using Type 347, great difficulty was experienced in attempting to eliminate hot tears, even when temperature and composition were held to extremely close limits. On the contrary, with Type 321 cast by the Solar process, no hot tears have as yet been encountered, even under adverse pouring conditions. Though a certain amount of fading of the titanium takes place, this can be controlled by adding properly sized ferrotitanium. A representative heat log showing titanium content of samples as a function of time after addition of the ferrotitanium is as follows:

TIME	TI	Y.S.	R.A.	ELONG.
0	*			
3 min.	0.32%			
5	0.45	36,500	43%	49%
7	0.53			
9	0.65	36,500	42	40
11	0.68			
13	0.72	38,000	37	40
15	0.66			
17	0.66			

*0.80% Ti added at one time.

No titanium is recovered from the scrap charge.

One other question of detail deserves final comment: H. Allsop has reasonably suggested that aluminum may have influenced our oxidation test results. Accordingly, we have analyzed our test samples for that element. Although both 321 and 347 showed apparently equal aluminum contents of less than 0.02% (the limit of sensitivity of wet analysis), spectrographic analyses indicated about twice as much aluminum in 321 as in 347. The difference between spectrographic and chemical results could have been caused by aluminum oxide inclusions, which would not show up in ordinary chemical analysis. In order to resolve this uncertainty, we checked a number of heats of 321 until a sample was found which gave no spectrographic traces of aluminum. This specimen was then tested for oxidation resistance at 1850° F. The results confirmed those presented in the original article.

TO SUMMARIZE: Columbium must be conserved and usually can be conserved by substituting less strategic alloys without adverse effect on service life. The successful substitution of titanium-stabilized steel in severe service in aircraft components and chemical process equipment indicates the desirability of re-evaluating all applications in which columbium-bearing alloys are specified. To paraphrase Mr. Evans' discussion, the working rule should be amended to read, "When in doubt, do *not* use columbium-bearing alloys".

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